# PROCEEDINGS

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## SECTION B—Vol. IV

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# INHERITANCE OF CERTAIN COLOUR CHARACTERS IN GRAM (CICER ARIETINUM).

By V. Ramanatha Ayyar

AND

R. Balasubramaniam.

(From the Agricultural Research Institute, Coimbatore.)

## 1. Introduction.

COLOUR of the seed-coat is an important factor in the marketing of gram (*Cicer arietinum*). It is reported that in Northern India, yellowish white seeds fetch a premium up to 50 % over the black and brown varieties, as the former is favoured for the manufacture of flours of lighter kind. The grams grown in the Madras Presidency have only a brown or cinnamon-red seed-coat. If only the colour of the Madras types can be altered into yellowish white with no modifications in other characters, it may result in a greater profit to the grower of gram. A knowledge of the mode of inheritance of the seed-coat colour forms a necessary pre-requisite for such a project. The data presented here relate to the investigations into the inheritance of some of the colour differences.

## 2. Previous Work.

Literature on the genetics of this crop is surprisingly scanty. In India investigations are being carried out by the Imperial Economic Botanist at Pusa since 1911. Khan and Akhtar (1934) studied the inheritance of petal colour in some of the Pusa types and reported that (1) a factor B is responsible for the blue colour of the petals, (2) that when B is in association with another factor P, the flowers are converted into pink, (3) that in the absence of B, they are white irrespective of the presence or absence of P, and (4) that the standard petal assumes a green colour when a factor W is absent.

Shaw (1928–29) and Alam (1935) studied modes of inheritance of the seed-coat colour in two sets of crosses made between Kabuli and Desi types. They merely stated that in the first cross (T.2 × T.18) the differences in the seed-coat colour were brought about by the interaction of 4 pairs of factors while in the second cross (T.1 × T.25) they were caused by three pairs of factors. They concluded that orange was the basic colour of gram seeds and that the colour and shape factors of seeds were linked. They indicated that brown and red seeds were produced from plants with pink petals, while white, fawn and orange seeds came from white-flowered types.

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### 3.  Methods.

In gram, there are three easily distinguishable colours in flowers, *viz.*, pink, blue and white, and there is little difficulty in sorting them out.

In the case of seed-coat, however, it was observed during the course of the preliminary studies that the colour varied very much even in the same plant according to the extent of development and filling of the seed. Storage after harvest also tended to alter the shades to a certain extent. Besides, the same vareity when grown in different places manifested a slightly different colour expression. For instance, Type 2 grown at Coimbatore had a different hue from that directly got from Pusa. With a view to maintain accuracy in classification, a series of 13 colour standards (which will be represented by the letters C. S. in the subsequent pages) were formed from well-filled dry seeds collected soon after harvest. These were then preserved in glass tubes filled with carbon-dioxide and hermetically sealed with paraffin. In addition, their colours were painted in water colours to serve as a basis for future reference (Plate I), and named after Ridgway's colour scales. Of the several standards considered here, C. Ss. 1, 2, 3, 7, 10 and 12 are alone represented in the parents used, while the rest have been obtained as recombination products of hybridisation.

For classification of the several variants, the produce of each plant was threshed and a few well-filled seeds were placed in a glass tube similar to those used for preserving the standards, and matched with them.

The genic constitution of each colour was decided finally by studying the nature of the ratios obtained in the several $F_3$ families. The method of back-crossing was not adopted, as the technique of artificial crossing was a slow process, and as the percentage of success, when attempted, was very low (Ramanatha Ayyar and Balasubramaniam, 1935).

In the study of the shape of the seeds, a broad classification of "irregular" and "round" was alone attempted. Even so, great difficulty was felt in spotting out "rounds," as these appeared very much like the "irregular" when immature. In general, a sample was declared round when it contained at least a few well-defined round seeds. It was experienced from the commencement of the classification of the colour standards that in C. Ss. 13, 11, 9, 7, 6, 5, 4 and 2, the seeds were round, while in C. Ss. 12, 10, 8, 3 and 1, they were irregular in shape.

### 4.  Material.

All the data furnished here relate to material obtained by direct crossing between pure lines isolated at Pusa and Coimbatore. Numbers prefixed by T refer to Pusa types, while those without it relate to types isolated

at Coimbatore. Many of the Pusa types when grown at the latter place were found to be very late. Most of them failed to set seed and even when they did, the number of seeds obtained was low with the result that only small populations were secured in many cases. The chief characteristics of the types used as parents are given in the following table.

<div align="center">TABLE I.</div>

| Description | Seeds-coat colour | | | Petal | | Seed form | Seed surface | Genic constitution of seed-coat colours |
|---|---|---|---|---|---|---|---|---|
| | C. S. No. | Name as per Ridgway's colour scale | | Colour | Genic constitution | | | |
| T. 6 | 1 | Warm buff | | white | CbP | Irregular | Smooth | bPt²t¹f' |
| T. 8 | 2 | Pale ochraceous Salmon | | ,, | CbP | Round | Puckered to wrinkled | bPt²t¹F' |
| T. 10 | 3 | Pinkish Cinnamon | | ,, | CbP | Irregular | Slightly granulated | bPT²t¹f' |
| T. 11 | 7 | Buffy brown | | ,, | cBp | Round | Smooth | BpT²t¹f' |
| T. 13 | 7 | ,, ,, | | Blue | CBp | ,, | ,, | BpT²t¹f' |
| T. 12 | 10 | Cinnamon | | White | cBP | Irregular | ,, | BPT²t¹f' |
| T. 82, 386, 416, 468, 493, 498 | 10 | ,, | | Pink | CBP | ,, | Smooth to granulated | BPT²t¹f' |
| T. 21, T. 24 19, 48 | 12 | Roods brown | | Pink | CBP | Irregular | Smooth to granulated | BPT²T¹f' |

In all cases, the flowers were not selfed, as pollination is complete (Ramanatha Ayyar and Balasubramaniam, 1935) long before the opening of the petals. No single instance of spontaneous cross pollination has been noticed so far, although thousands of plants were grown side by side.

### 5. Description of the factorial scheme.

It will be shown in this paper that three pairs of factors Cc, Bb, Pp are involved in the production of pink, blue and white petals, and three more pairs F'f', T¹t¹, T²t² in the formation of the thirteen grades of seed colour [Table II (*b*)].

Factor B has manifold effects on plant characters. It imparts blue colour to petals when it is in association with C, and pink in the combined presence of C and P. The petals are white when it is absent. It converts the basic warm buff colour of the seeds into dark olive buff. It inhibits the colour effects of F' when the recessive factor p is present. It reduces the

size of the seeds and gives them a round shape when it is in association with the allele of P.

Factor C acts as a complementary factor to B in the production of petal colours. In other respects it seems to have no visible reaction.

Factor P by itself has no action either on flower or seed-coat colours. Its presence is felt only when it acts as a supplementary factor to B. In CBP condition blue petals are changed into pink, and dark olive buff coloured seeds into pinkish buff [Table II (b)]. Further, the epistatic and size depressing properties of factor B are lost. $T^1$ has been found to possess no colour reaction with the recessive gene p.

Factor $F^r$ is another factor with pleiotropic effects. It has no reaction on flower colour but has varying effects on seed-coat colours according to the nature of the genic background [Table II (a)]. When it is added

TABLE II (a).

| Basic formula for seed-coat | Factors added | Resultant colour standard (C.S.) | Remarks |
|---|---|---|---|
| $bpf^rt^1t^2$ | Nil | 1 | |
| ,, | B | 5 | |
| ,, | P | 1 | |
| ,, | $F^r$ | 2 | |
| ,, | $T^1$ | .. | Yet to be studied |
| ,, | $T^2$ | 3 | |
| ,, | B + P | 8 | |
| ,, | B + $F^r$ | 6 | |
| ,, | B + $T^1$ | .. | Do. |
| ,, | B + $T^2$ | 7 | |
| ,, | P + $F^r$ | 2 | |
| ,, | P + $T^1$ | .. | Do. |
| ,, | P + $T^2$ | 3 | |
| ,, | $F^r$+ $T^1$ | .. | Do. |
| ,, | $F^r$+ $T^2$ | 4 | |
| ,, | $T^1$+ $T^2$ | .. | Do. |
| ,, | B + P + $F^r$ | 9 | |
| ,, | B + P + $T^1$ | .. | Do. |
| ,, | B + P + $T^2$ | 10 | |
| ,, | B + $F^r$+ $T^1$ | .. | Do. |
| ,, | B + $F^r$+ $T^2$ | 7 | |
| ,, | B + $T^1$+ $T^2$ | 7 | |
| ,, | P + $F^r$+ $T^1$ | .. | Do. |
| ,, | P + $F^r$+ $T^2$ | 4 | |
| ,, | P + $T^1$+ $T^2$ | .. | Do. |
| ,, | $F^r$+ $T^1$+ $T^2$ | .. | Do. |
| ,, | B + P +$F^r$+ $T^1$ | .. | Do. |
| ,, | B + P +$F^r$+ $T^2$ | 11 | |
| ,, | B + $F^r$+$T^1$+ $T^2$ | .. | Do. |
| ,, | B + P +$T^1$+ $T^2$ | 12 | |
| ,, | P + $F^r$+$T^1$+ $T^2$ | .. | Do. |
| ,, | B +P+$F^r$+$T^1$+$T^2$ | 13 | |

to the basic colour, it dilutes its intensity as in C. Ss. 2 and 4. When it is in conjunction with B and P, it intensifies the colour as in C. S. 9. With B,

P and T², it enhances the black component as in C. Ss. 11 and 13.   The colour effects are, however, inhibited when it is in association with B only as in C. Ss. 6 and 7.   It gives round shape to irregular seeds which feature is hypostatic in Bp combinations.   It reacts also on the seed surface except when it is not associated with B and T².

Factor T¹ has no action on flower colour.   It augments blackness of the seed-coat in the presence of P [Table II (*b*)].   Its effects with other combinations are under study.

<div align="center">TABLE II (*b*).</div>

| Character | Colour standard | Name of the colours | Genic formula | Composition of the colours* | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Neutral gray | White | Orange | Yellow | Black |
| Flower colour | | Pink | CBP | | | | | |
| " | | Blue | CBp | | | | | |
| " | | White | cBP, cBp, cbP CbP, Cbp, cbp | | | | | |
| Seed-coat colour | C. S. 1 | Warm buff | bpf″t¹t² or bPf″t¹t² | 32 | 22·5 | 50·4 | 27·1 | .. |
| | C. S. 2 | Pale ochraceous Salmon | bpF″t¹t² or bPF″t¹t² | 32 | 45·0 | 50·0 | 5·0 | .. |
| | C. S. 3 | Pinkish cinnamon | bpf″t¹T² or bPf″t¹T² | 58 | 9·5 | 72·4 | 18·1 | .. |
| | C. S. 4 | Light pinkish cinnamon | bpF″t¹T² or bPF″t¹T² | 58 | 22·5 | 62·0 | 15·5 | .. |
| | C. S. 5 | Dark olive buff | Bpf″t¹t² | 77 | .. | 25·0 | 75·0 | .. |
| | C. S. 6 | " | BpF″t¹t² | 77 | .. | 25·0 | 75·0 | .. |
| | C. S. 7 | Buffy brown | Bpf″t¹T² or BpF″t¹T² or Bpf″T¹T² | 77 | .. | 35·7 | 19·3 | 45·0 |
| | C. S. 8 | Pinkish buff | BPf″t¹t² | 58 | 22·5 | 50·4 | 27·1 | .. |
| | C. S. 9 | Cinnamon buff | BPF″t¹t² | 58 | 9·5 | 58·8 | 31·7 | .. |
| | C. S 10 | Cinnamon | BPf″t¹T² | 58 | .. | 80·0 | 20·0 | .. |
| | C. S. 11 | Sayal brown | BPF″t¹T² | 58 | .. | 44·0 | 11·0 | 45·0 |
| | C. S. 12 | Roods brown | BPf″T¹T² | 58 | .. | 29·5 | .. | 70·5 |
| | C. S. 13 | Vandyke brown | BPF″T¹T² | 58 | .. | 12·5 | .. | 87·5 |

* Copied from Ridgway's colour standards.

Factor T² has no chromatic reaction on petals.   In the production of. seed colours, it intensifies, in some cases, the orange component (C. Ss. 3 and 10) and in other cases imparts a black shade (C. Ss. 7 and 11).

The effects of several combinations on the chromatic scheme of seed and petals are given in Table II (*a*) for easy reference. The all recessive condition is represented by C. S. 1.

### 6. *Experimental Results.*

(*a*) *Flower colour factors.*—Petal colour was observed in all the crosses made for the study of the inheritance of seed-coat colours. Since the inheritance of this character has been dealt with extensively by Khan and Akhtar, the data which do not conform to their hypothesis alone are presented in Table III.

TABLE III.

| Parents used | Petal colour of $F_1$ | Number of families studied | Total number of plants | Actual number obtained | | | *Expected ratio* | Value of P |
|---|---|---|---|---|---|---|---|---|
| | | | | Pink | Blue | White | | |
| T. 8 × T. 11 — ($F_2$) | Pink | 17 | 525 | 211 | 77 | 237 | *27 : 9 : 28* | > 0·50 |
| T. 8 × T. 12 — ($F_2$) | Do. | 7 | 84 | 48 | | 36 | 9 : 0 : 7 | > 0·90 |
| T. 10 × T. 12 — ($F_2$) | Do. | 4 | 199 | 116 | | 83 | 9 : 0 : 7 | > 0·80 |

It was interesting to find that crossing two white flowered types resulted in $F_1$s with pink petals, and that ratios of 3 : 1, 9 : 7, 9 : 3 : 4 and 27 : 9 : 28 were obtained in $F_2$ progenies. Since the production of pink coloured $F_1$ and the ratio of 9 : 7 and 27 : 9 : 28 could not be accounted for by the hypothesis formulated by Khan and Akhtar, a modification had been suggested. The occurrence of the trihybrid ratio of 27 : 9 : 28 clearly indicates that three factors are involved. The ratio of 9 : 7 points out that two of them are complementary in nature, and the ratio of 9 : 3 : 4 shows that the third factor behaves supplementary to one of the complementary factors. In view of the fact that Khan and Akhtar have used symbols Bb and Pp to represent two of the factors, it is proposed to designate the third as Cc. According to this representation B and C will be complementary, and P supplementary to B. The new hypothesis will be that the combination of B and C produces blue petals and a further addition of P converts blue into pink. The genic constitution of the homozygous pink and blue will respectively be CCBBPP and CCBBpp. The white flowered phenotypes will have any of the six possible genic formulæ, *viz.*, CCbbPP, CCbbpp, ccBBpp, ccBBPP, ccbbPP and ccbbpp. The fact that types with three different genic constitutions have been found to be present among the cultivated white flowered Pusa types (Appendix) supports the above scheme.

The above hypothesis also explains how the trihybrid ratio for independent segregation, *viz.*, 27 CBP : 9 CBp : 9 cBP : 9 CbP : 3 Cbp : 3 cBp : 3 cbP : 1 cbp has been converted into one of 27 pink : 9 blue : 28 whites.

(*b*)   *Seed-coat colour factors.*—All the deductions drawn in this section could have been obtained from the sub-sections vi to viii alone. The others are included here for the reason that they enable the reader to follow the effects of each factor more easily.

For the sake of clearness the factors that show segregations are underlined in the genic formulæ given against the colour standards at the commencement of each sub-section.

$$\text{(i) Roods brown (C. S. 12) } BPf^r\underline{T^1}T^2$$
$$\times$$
$$\text{Cinnamon (C. S. 10) } BPf^r\underline{t^1}T^2.$$

Seven sets of crosses were studied. Details of the three sets that were followed to $F_3$ are alone furnished in Table IV.

TABLE IV.

*(To show segregations for factor $T^1$.)*

| Parents | Generation | Parent seed colour C. S. | Number of families studied | Total Number of plants | Actual number of Plants obtained Pink Petal | | Expected ratio | Value of P |
|---|---|---|---|---|---|---|---|---|
| | | | | | C. S. 12 $T^1$ | C.S. 10 $t^1$ | | |
| 19×468 | $F_2$ | 12 | 1 | 87 | 67 | 20 | *3 : 1* | >0·50 |
| | $F_3$ | 10 | 13 | 424 | | All | | |
| | ,, | 12 | 7 | 145 | All | | | |
| | ,, | 12 | 16 | 538 | 386 | 152 | *3 : 1* | >0·05 |
| T. 24×386 | $F_2$ | 12 | 5 | 152 | 111 | 41 | *3 : 1* | >0·50 |
| | $F_3$ | 10 | 11 | 49 | | All | | |
| | ,, | 12 | 9 | 32 | All | | | |
| | ,, | 12 | 13 | 70 | 49 | 21 | *3 : 1* | >0·30 |
| T. 24×493(1) | $F_2$ | 12 | 1 | 116 | 73 | 43 | *3 : 1* | >0·01 |
| | $F_3$ | 10 | 5 | 210 | | All | | |
| | ,, | 12 | 1 | 29 | All | | | |
| | ,, | 12 | 8 | 322 | 236 | 86 | *3 : 1* | >0·30 |
| Do.   (3) | $F_2$ | 12 | 1 | 70 | 50 | 20 | *3 : 1* | >0·30 |
| | $F_3$ | 10 | 1 | 35 | | All | | |
| | ,, | 12 | 1 | 27 | All | | | |
| | ,, | 12 | 3 | 80 | 57 | 23 | *3 : 1* | >0·30 |
| Do.   (4) | $F_2$ | 12 | 1 | 83 | 56 | 27 | *3 : 1* | >0·10 |
| | $F_3$ | 10 | 2 | 105 | | All | | |
| | ,, | 12 | 4 | 127 | All | | | |
| | ,, | 12 | 4 | 129 | 99 | 30 | *3 : 1* | >0·50 |

$F_1$ was Roods brown. $F_2$ gave a simple mono-genic ratio which was supported by the behaviour of the $F_3$ progenies.

The fit for monohybrid ratio was low when the data for all the families in the cross T. 24 × 493 were combined. The figures for each $F_2$ family are

therefore given separately. It will be seen that it is only in one family, the results are not satisfactory. But even there, the performance in $F_3$ is in conformity with those observed in other crosses.

It is clear that only one pair of factors is responsible for the seed colour differences noted between the parents. It is proposed to designate it by $T^1t^1$.

<div align="center">

(ii) Cinnamon (C. S. 10) $BPf^rt^1T^2$

×

Buffy brown (C. S. 7) $Bpf^rt^1T^2$.

</div>

Two crosses were studied. $F_1$s had pink flowers, and cinnamon-coloured seeds. $F_2$s segregated for both flower and seed-coat colours (Table V).

<div align="center">

TABLE V.

*(To show segregations for factor P in the first and third crosses, P and C in the second cross.)*

</div>

| Parents | Generation | Parent seed colour | Number of families studied | Total number of plants | Actual number of plants obtained | | | | Expected ratio | Value of P |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Pink petal C.S. 10 CP | Blue petal C.S. 7 Cp | White petal | | | |
| | | | | | | | C.S. 10 cP | C.S. 7 cp | | |
| 493×T. 13 | $F_2$ | C.S. 10 | 2 | 57 | 45 | 12 | | | *3 : 1* | >0·20 |
| | $F_3$ | 7 | 5 | 25 | | All | | | | |
| | ,, | 10 | 3 | 81 | All | | | | | |
| | ,, | 10 | 4 | 140 | 108 | 32 | | | *3 : 1* | >0·50 |
| | $F_2$ | 10 | 1 | 41 | 24 | 6 | 9 | 2 | *9 : 3 : 3 : 1* | >0·80 |
| T. 12×T. 13 | $F_3$ | 7 | 1 | 3 | | | | All | | |
| | ,, | 7 | 2 | 5 | | All | | | | |
| | ,, | 7 | 1 | 12 | | 10 | | 2 | *3 : 1* | >0·50 |
| | ,, | 10 | 4 | 55 | | | All | | | |
| | ,, | 10 | 5 | 77 | | | 57 | 20 | *3 : 1* | >0·80 |
| | ,, | 10 | 1 | 15 | 10 | | 5 | | *3 : 1* | >0·50 |
| | ,, | 10 | 1 | 11 | 9 | 2 | | | *3 : 1* | >0·50 |
| | ,, | 10 | 4 | 88 | 50 | 18 | 14 | 6 | *9 : 3 : 3 : 1* | >0·80 |
| T. 12×T. 11 | $F_2$ | 10 | 8 | 395 | | | 298 | 97 | *3 : 1* | >0·90 |

It is obvious from the mono-hybrid ratio of the first cross (493 × T.13) that only one pair of factors is concerned in the production of colour differences.   Since all the pink flowered plants produce only cinnamon coloured seeds, and all the blue petalled plants only buffy brown seeds, and since it is known [*vide* subsection (*a*)] that gene P is responsible for the conversion of blue into pink flowers, it can be taken that a gene identical to or completely linked with P causes the differences in the colour standards.   As it is desirable to avoid increasing the number of factors till such a step is found absolutely essential, it is taken for the present that gene P causes the the above seed colour differences.

This deduction has been confirmed by the results obtained in the cross between T.11 and T.12.   Both these types have white flowers but differ in the presence of P (*vide* Appendix).   In $F_2$, C. S. 10 and C. S. 7 alone are produced (*vide* last line of Table V) showing thereby that P is the cause for the differences noted in the seed colours.

In the second cross T.13 × T.12 there is segregation for petal colour in both colour standards yielding a straightforward digenic ratio.   As the genic formula for flower colour of T.13 is CBp and that of T.12 is cBP (*vide* Appendix) it is clear that the dihybrid ratio is brought about by the segregation of factors P and C.   But there are only two phenotypes in seed colour which have been proved in the cross described in the previous para to be due to the segregation of P.   It may, therefore, be concluded that factor C has effect only in the production of flower colour and not on the seed colour.

$$\text{(iii)}\quad \text{Cinnamon (C. S. 10)}\ \underline{B}\underline{P}f^r t^1 T^2$$
$$\times$$
$$\text{Warm buff (C. S. 1)}\ b\underline{P}f^r t^1 t^2.$$

Three sets of crosses were studied in $F_2$ and only one was pursued to $F_3$. Cinnamon was again dominant in $F_1$.

A simple digenic ratio with four phenotypes was obtained in $F_2$.   The behaviour of $F_3$ was according to expectation. Pinkish cinnamon (C. S. 3) and a new colour segregate—pinkish buff (C. S. 8)—were obtained (*vide* Table VI) besides the parental colours.

Obviously two factors are involved here.   One of them, as will be seen presently, is B and the other is new and is represented by $T^2 t^2$.   By its addition C. Ss. 1 and 8 are converted into C. Ss. 3 and 10 respectively.

Seeds of C.Ss. 3 and 1 are produced from white flowers only while those of C.Ss. 10 and 8 are obtained from pink flowers.   It is justifiable to infer that a gene identical to, or completely linked with, a gene concerned in the segregation of pink and white flowers is one of the two genes responsible for

TABLE VI.

*(To show segregations for factors B and $T^2$.)*

| Parents | Generation | Parent seed colour | Number of families studied | Total number of plants | Actual number of plants obtained | | | | Expected ratio | Value of P |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Pink petal | | White petal | | | |
| | | | | | C. S. 10 $BT^2$ | C. S. 8 $Bt^2$ | C. S. 3 $bT^2$ | C. S. 1 $bt^2$ | | |
| 493 × T. 6 | $F_2$ | C.S. 10 | 2 | 110 | 58 | 18 | 26 | 8 | 9:3:3:1 | >0·50 |
| ,, | $F_3$ | 1 | 7 | 68 | | | | All | | |
| ,, | ,, | 3 | 6 | 106 | | | All | | | |
| ,, | ,, | 3 | 11 | 171 | | | 126 | 45 | 3:1 | >0·70 |
| ,, | ,, | 8 | 4 | 58 | | All | | | | |
| ,, | ,, | 8 | 6 | 123 | | 92 | | 31 | 3:1 | 1·00 |
| ,, | ,, | 10 | 3 | 115 | All | | | | | |
| ,, | ,, | 10 | 5 | 55 | 42 | | 13 | | 3:1 | >0·70 |
| ,, | ,, | 10 | 8 | 210 | 159 | 51 | | | 3:1 | >0·80 |
| ,, | ,, | 10 | 13 | 469 | 275 | 80 | 80 | 34 | 9:3:3:1 | >0·30 |

the differences in the seed-coat colours noted. It has been shown previously that white flowers will arise from pink, when either of the recessive factors c or b is present. It has been found that T. 6 has the same genic constitution as T. 8 for flower colour and that T. 8 is represented by CbP. Further it has been shown that C has no effect in the production of seed colour [*vide* subsection (*b*) ii]. It follows, therefore, that recessive condition b in T. 6 is responsible for the white petal in C. S. 3 and C. S. 1.

(iv) Pinkish cinnamon (C. S. 3) $bP\underline{f^r t^1} T^2$
×
Pale ochraceous Salmon (C. S. 2) $bP\underline{F^r t^1 t^2}$.

Only one cross was studied. $F_1$ was light pinkish cinnamon (C. S. 4)— a new colour grade. In the $F_2$ a straightforward dihybrid ratio for independent segregation was obtained (Table VII).

TABLE VII.

*(To show segregations for factors $T^2$ and $F^r$.)*

| Parents | Parent seed colour | Number of families | Total number of plants | Actual number obtained | | | | Expected ratio | Value of P |
|---|---|---|---|---|---|---|---|---|---|
| | | | | C. S. 4 $F^r T^2$ | C. S. 3 $f^r T^2$ | C. S. 2 $F^r t^2$ | C. S. 1 $f^r t^2$ | | |
| T. 10 × T. 8 (F₂) | C. S. 4 | 13 | 200 | 113 | 40 | 33 | 14 | 9:3:3:1 | >0·80 |

Of the two factors involved here, it has been shown [*vide* subsection (*b*) iii] that C. S. 3 is caused by the addition of factor $T^2$ to C. S. 1. The other gene is new and is designated by $F^rf^r$, on account of its prominent effect on seed form. It will be seen later on that $F^r$ is responsible for the round shape of seeds also.

$$\text{(v)   Cinnamon (C. S. 10) } \underline{B}P\underline{f^r}t^1\underline{T^2}$$
$$\times$$
$$\text{Pale ochraceous Salmon (C. S. 2) } \underline{b}P\underline{F^r}t^1\underline{t^2}.$$

Four sets of crosses were examined in $F_2$ and three were followed to $F_3$. As the results of all of them are similar, the results of one cross (493 × T. 8) alone are presented here.

$F_1$ had a new colour—Sayal brown (C. S. 11). There were 8 phenotypes in $F_2$ and the numerical results corresponded to a simple trihybrid ratio pertaining to independent assortment of three genes. Two new colour standards (C. Ss. 11 and 9) were obtained (Table VIII) in addition to the parental colours C. S. 10 and C. S. 2 and the three standards C. Ss. 8, 3 and 1 already dealt with.

In the $F_3$ families simple trihybrid, dihybrid and mono-hybrid segregations were obtained from C. S. 11, while only dihybrid and mono-hybrid ratios were got in C. Ss. 10, 9 and 4, and mono-hybrid ratios in C. Ss. 8, 3 and 2. C. S. 1 did not split at all indicating thereby that it represented the all recessive. The mode of segregation thus supports a three factorial scheme of independent assortment. In the two previous subsections the interplay of factors $T^2$ and B, and of $T^2$ and $F^r$ have been demonstrated. It is seen here that when all the three get involved in a cross, they segregate independently without any interaction. The occurrence of pink flowers in C. Ss. 11, 10, 9 and 8 and of white flowers in C. Ss. 4, 3, 2, and 1 are easily accounted for by the interplay of factors Bb. The production of the new colour Sayal brown (C. S. 11) is due to the introduction of the factor $F^r$ into cinnamon (C. S. 10) from the T. 8 parent.

$$\text{(vi)   Roods brown (C. S. 12) } B\underline{P}f^r\underline{T^1}T^2$$
$$\times$$
$$\text{Buffy brown (C. S. 7) } B\underline{p}f^r\underline{t^1}T^2.$$

The cross studied was T.21 × T.13.

$F_1$ was Roods brown.

## TABLE VIII.

*(To show segregations for factors B, T² and Fʳ.)*

| Parents | Generation | Parent seed colour | No. of families studied | Total number of plants | Actual number of plants | | | | | | | | Expected ratio | Value of P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Pink petal | | | | White petal | | | | | |
| | | | | | C.S. 11 | C.S. 10 | C.S. 9 | C.S. 8 | C.S. 4 | C.S. 3 | C.S. 2 | C.S. 1 | | |
| | | | | | BT²Fʳ | BT²Fʳ | Bt²Fʳ | Bt²Fʳ | bT²Fʳ | bT²Fʳ | bt²Fʳ | bt²Fʳ | | |
| 493 × T. 8 | F₂ | C.S. 11 | 7 | 386 | 169 | 58 | 59 | 21 | 43 | 18 | 11 | 7 | 27 : 9 : 9 : 9 : 3 : 3 : 3 : 1 | >0·30 |
| | F₃ | 1 | 3 | 50 | | | | | | | | All | | |
| | ,, | 2 | 3 | 38 | | | | | | All | | | | |
| | ,, | 2 | 2 | 28 | | | | | | | 21 | 7 | 3 : 1 | 1·00 |
| | ,, | 3 | 2 | 22 | | | | | All | | | | | |
| | ,, | 3 | 3 | 46 | | | | | | 35 | | 11 | 3 : 1 | >0·80 |
| | ,, | 4 | 1 | 5 | | | | | All | | | | | |
| | ,, | 4 | 2 | 27 | | | | | 19 | 8 | | | 3 : 1 | >0·50 |
| | ,, | 4 | 1 | 10 | | | | | 7 | | 3 | | 3 : 1 | >0·70 |
| | ,, | 4 | 5 | 96 | | | | | 54 | 15 | 20 | 7 | 9 : 3 : 3 : 1 | >0·80 |
| | ,, | 8 | 1 | 9 | | | | All | | | | | | |
| | ,, | 8 | 6 | 174 | | | | 130 | | | | 44 | 3 : 1 | >0·90 |
| | ,, | 9 | 2 | 16 | | | All | | | | | | | |
| | ,, | 9 | 3 | 77 | | | 57 | 20 | | | | | 3 : 1 | >0·70 |
| | ,, | 9 | 7 | 156 | | | 115 | | | 41 | | | 3 : 1 | >0·70 |
| | ,, | 9 | 7 | 215 | | | 122 | 39 | | 39 | 15 | | 9 : 3 : 3 : 1 | >0·90 |
| | ,, | 10 | 2 | 54 | | All | | | | | | | | |
| | ,, | 10 | 1 | 42 | | 32 | | | 10 | | | | 3 : 1 | >0·80 |
| | ,, | 10 | 3 | 131 | | 96 | | 35 | | | | | 3 : 1 | >0·50 |
| | ,, | 10 | 6 | 182 | | 93 | | 38 | | 37 | | 14 | 9 : 3 : 3 : 1 | >0·50 |
| | ,, | 11 | 1 | 21 | 15 | 6 | | | | | | | 3 : 1 | >0·50 |
| | ,, | 11 | 1 | 7 | 5 | | | | 2 | | | | 3 : 1 | >0·90 |
| | ,, | 11 | 2 | 58 | 28 | 14 | 9 | 7 | | | | | 9 : 3 : 3 : 1 | >0·10 |
| | ,, | 11 | 1 | 18 | 9 | | 2 | | 6 | 1 | | | 9 : 3 : 3 : 1 | >0·30 |
| | ,, | 11 | 3 | 79 | 36 | 8 | 10 | 7 | 8 | 3 | 5 | 2 | 27 : 9 : 9 : 9 : 3 : 3 : 3 : 1 | >0·50 |

F$_2$ had only three phenotypes C. S. 12, 10 and 7 and the numerical results approximated to the modified digenic ratio of 9 : 3 : 4. All the plants in C. S. 7 had only blue flowers (Table IX).

TABLE IX.

*(To show segregations for factors P and T$^1$.)*

| Parents | Generation | Parent seed colour | Number of families studied | Total number of plants | Actual number of plants obtained | | | Expected ratio | Value of P |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Pink petal | | Blue petal | | |
| | | | | | C.S. 12 PT$^1$ | C.S. 12 l't$^1$ | C. S. 7 pT$^1$ & pt$^1$ | | |
| T. 21×T. 13 | F$_2$ | C.S. 12 | 2 | 49 | 27 | 9 | 13 | *9 : 3 : 4* | >0·90 |
| | F$_3$ | 7 | 4 | 26 | | | All | | |
| | ,, | 10 | 2 | 4 | | All | | | |
| | ,, | 10 | 1 | 4 | | 2 | 2 | *3 : 1* | >0·20 |
| | ,, | 12 | 2 | 2 | All | | | | |
| | ,, | 12 | 3 | 7 | 4 | 3 | | *3 : 1* | >0·30 |
| | ,, | 12 | 4 | 46 | 33 | | 13 | *3 : 1* | >0·70 |
| | ,, | 12 | 7 | 64 | 35 | 14 | 15 | *9 : 3 : 4* | >0·50 |

F$_3$ results were in accordance with the genic constitution indicated in F$_2$. C. S. 7 did not segregate. The heterozygous families in C. S. 12 gave again 3 : 1 and 9 : 3 : 4 ratios, and those in C. S. 10 yielded monohybrid ratios. It may be recalled that the colour differences between C. S. 12 and C. S. 10 have been brought about by the presence of genes T$^1$t$^1$ [*vide* subsection (*b*) i] and that those between C. Ss. 10 and 7 by genes Pp [*vide* subsection (*b*) ii]. One should expect four phenotypes corresponding to the combinations PT$^1$, Pt$^1$, pT$^1$ and pt$^1$ in a F$_2$ of a cross between C. Ss. 12 and 7. Of these, the last two, though of different genic constitution, are now found to possess the same phenotypic effect which accounts for the 9 : 3 : 4 ratio. It is therefore concluded that gene T$^1$ has no separate effect on seed-coat colour when gene P is absent.

(vii) Buffy brown (C. S. 7) $\underline{B}pf^rt^1T^2$

$\times$

Pinkish cinnamon (C. S. 3) $b\underline{P}f^rt^1T^2$.

Only one set of cross was studied. The F$_1$ had cinnamon (C. S. 10) coloured seeds. The F$_2$ showed a digenic ratio of 9 cinnamon : 3 buffy

brown : 4 pinkish cinnamon (Table X) which exactly corresponded to the ratios between pink, blue and white flowers.

TABLE X.

*(To show segregations for factors B and P.)*

| Parents | $F_1$ colour grade | Number of families studied | Total number of plants | Actual number of plants | | | Expected ratio | Value of P |
|---|---|---|---|---|---|---|---|---|
| | | | | Pink C.S. 10 BP | Blue C.S. 7 Bp | White C.S. 3 bP & bp | | |
| T. 13×T. 10 (F$_2$) | C. S. 10 | 6 | 160 | 94 | 29 | 37 | 9 : 3 : 4 | >0·80 |

It is obvious that the same set of genes should account for the differences observed in the flower and seed-coat colours. It is known that the formula for flower colour in T. 13 is CBp and that of T. 10 (*vide* Appendix) is CbP and hence the factors involved in the above segregation are B and P. The increase in the proportion of white flowered phenotype is explainable as the two genotypes, bP and bp (which will be white in the recessive condition of B) are present there. In other words, factor P does not show any distinct chromatic reaction with the allele of B, in both schemes of flower and seed-coat colours.

(viii)  Buffy brown (C. S. 7) $B p f^r t^1 T^2$
× 
Pale ochraceous Salmon (C. S. 2) $b P F^r t^1 t^2$.

Two sets of crosses were studied with interesting results. In one of them (T. 8 × T. 13) the investigations were followed to $F_4$ generation.

$F_1$ was Sayal brown. $F_2$ gave eleven phenotypes (Table XI) of which two (C. Ss. 6 and 5) appeared for the first time.

TABLE XI.

(*To show segregation for factors B, P, T² and Fr¹.*)

| Parents | Generation | Parent seed colour | No. of families studied | Total number of plants | Pink petal C.S.11 BPT2fr | Pink petal C.S.10 BPT2fr | Pink petal C.S.9 BPt2Fr | Blue petal C.S.8 BPt2fr | Blue petal C.S.7 bPt2Fr & ibPT2fr | Blue petal C.S.6 Bpt2Fr | Blue petal C.S.5 Bpt2fr | White petal C.S.4 bPT2Fr & bpT2Fr | White petal C.S.3 bPT2fr & bpT2fr | White petal C.S.2 bPt2Fr & bpt2Fr | White petal C.S.1 bPt2fr & bpt2fr | Expected ratio | Value of P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T.8×T.11* | $F_2$ | 11 | 17 | 352 | $\frac{92}{33}$ | $\frac{30}{15}$ | $\frac{27}{9}$ | $\frac{10}{4}$ | $\frac{34}{13}$ | $\frac{11}{4}$ | $\frac{2}{1}$ | 35 | 13 | 15 | 4 | $\frac{243}{81}:\frac{81}{27}:\frac{81}{27}:\frac{27}{9}:\frac{108}{36}:\frac{81}{27}:\frac{9}{3}:144:48:48:16:\frac{9}{3}$ | > 0·80 |
| T.8×T.13 | $F_2$ | 11 | 3 | 172 | 53 | 18 | 22 | 8 | 21 | 9 | 3 | 22 | 4 | 9 | 3 | $81:27:27:9:36:9:3:36:12:12:4$ | > 0·70 |
| | $F_3$ | 1 | 2 | 6 | | | | | | | | | | | All | | |
| | " | 2 | 1 | 4 | | | | | | | | | | All | | | |
| | " | 2 | 2 | 21 | | | | | | | | | | 16 | 5 | 3 : 1 | > 0·90 |
| | " | 3 | 2 | 28 | | | | | | | | | All | | | | |
| | " | 3 | 3 | 41 | | | | | | | | | 31 | | 10 | 3 : 1 | > 0·90 |
| | " | 4 | 4 | 23 | | | | | | | | All | | | | | |
| | " | 4 | 2 | 7 | | | | | | | | 5 | 2 | | | 3 : 1 | > 0·60 |
| | " | 4 | 3 | 15 | | | | | | | | 11 | | 4 | | 3 : 1 | > 0·90 |
| | " | 4 | 8 | 103 | | | | | | | | 61 | 21 | 14 | 7 | 9 : 3 : 3 : 1 | > 0·50 |
| | $F_3$ & $F_4$ | 5 | 12 | 232 | | | | | | All | | | | | | | |
| | " | 5 | 5 | 115 | | | | | | | 86 | | | | 29 | 3 : 1 | > 0·90 |

* This cross segregates for factor C also.   The denominator denotes the number of plants with white petal in the respective C. Ss.

TABLE XI. (*Contd.*)

| Parents | Generation | Parent seed colour | No. of families studied | Total number of plants | Pink petal C.S.11 $BPt_2F$ | C.S.10 $BPt_2F$ | C.S.9 $BPt_2F$ | Blue petal C.S.8 $BPt_2f$ | C.S.7 $BPt_2F$ & $bpt_2F$ | C.S.6 $BPt_2F$ | C.S.5 $Bpt_2f$ | White petal C.S.4 $BPt_2F$ & $bbpt_2F$ | C.S.3 $BPt_2F$ & $bbpt_2F$ | C.S.2 $BPt_2F$ & $bbpt_2F$ | C.S.1 $Bpt_2F$ & $bbpt_2F$ | Expected ratio | Value of P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T.8 × T.13 | F$_4$ | 6 | 16 | 338 | | | | | | All | | | | | | | |
| | " | 6 | 7 | 136 | | | | | | 103 | 33 | | | | | 3:1 | >0·80 |
| | " | 6 | 10 | 153 | | | | | | 117 | | | | 36 | | 3:1 | >0·50 |
| | " | 6 | 7 | 202 | | | | | | 111 | 41 | | | 37 | 13 | 9:3:3:1 | >0·90 |
| | " | 7 | 22 | 225 | | | | | All | | | | | | | | |
| | " | 7 | 9 | 141 | | | | | 106 | | | 35 | | | | 3:1 | >0·90 |
| | " | 7 | 6 | 64 | | | | | 46 | 18 | | | | | | 3:1 | >0·50 |
| | " | 7 | 9 | 142 | | | | | 104 | | | | 38 | | | 3:1 | >0·50 |
| | " | 7 | 6 | 62 | | | | | 48 | | 14 | | | | | 3:1 | >0·50 |
| | " | 7 | 4 | 41 | | | | | 26 | | 11 | | | | 4 | 12:3:1 | >0·10 |
| | " | 7 | 3 | 57 | | | | | 32 | | | 10 | 5 | 10 | | 9:3:3:1 | >0·90 |
| | " | 7 | 6 | 128 | | | | | 89 | 26 | 13 | | | | | 12:3:1 | >0·50 |
| | " | 7 | 10 | 209 | | | | | 117 | 41 | | 41 | 10 | | | 9:3:3:1 | >0·80 |
| | " | 7 | 6 | 223 | | | | | 117 | 33 | 13 | 34 | 11 | 10 | 5 | 36:9:9:9:3:3:1 | >0·80 |
| | F$_3$ | 8 | 1 | 1 | | | | All | | | | | | | | | |

TABLE XI. (Contd.)

| Parents | Generation | Parent seed colour | No. of families studied | Total number of plants | Pink petal | | | Blue petal | | | | White petal | | | | Expected ratio | Value of P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | C.S.11 $BPt_2F_r$ | C.S.10 $BPt_2f_r$ | C.S.9 $BPt_2F_r$ | C.S.8 $BPt_2f_r$ | C.S.7 $BpT_2F_r$ & $BpT_2f_r$ | C.S.6 $Bpt_2F_r$ | C.S.5 $bpt_2F_r$ & $bpt_2f_r$ | C.S.4 $bPt_2F_r$ & $bpT_2F_r$ | C.S.3 $bPt_2f_r$ & $bpT_2f_r$ | C.S.2 $bpt_2F_r$ & $bpt_2F_r$ | C.S.1 $bpt_2f_r$ & $bpt_2f_r$ | | |
| T.8×T.13 | $F_8$ | 11 | 2 | 19 | 12 | | 7 | | | | | | | | | 3:1 | >0.20 |
| | ,, | 11 | 1 | 5 | 2 | | | | 2 | | | | | | | 9:3:4 | >0.30 |
| | ,, | 11 | 1 | 39 | 24 | 4 | 3 | 0 | 11 | | | | | | | 9:3:4 | >0.30 |
| | ,, | 11 | 1 | 19 | 13 | 3 | 3 | | | | | 1 | | | | 9:3:3:1 | >0.50 |
| | ,, | 11 | 1 | 19 | 12 | | 7 | | | | | | | | | 9:3:3:1 | >0.20 |
| | ,, | 11 | 2 | 32 | 13 | | | | 9 | 3 | | 3 | | 1 | | 9:3:3:1 | >0.30 |
| | ,, | 11 | 2 | 15 | 9 | 2 | 4 | 2 | | | | 3 | 1 | | | 9:3:3:1 | >0.90 |
| | ,, | 11 | 1 | 28 | 11 | 8 | 4 | | | | | 2 | 1 | | | 27:9:9:9:3:3:1 | >0.30 |
| | ,, | 11 | 2 | 43 | 20 | | | | 8 | 2 | | 6 | | 0 | 0 | 27:9:3:12:4 | >0.80 |
| | ,, | 11 | 2 | 41 | 17 | 6 | | | 9 | | | 7 | 2 | 3 | | 27:9:12:12:4 | >0.90 |
| | ,, | 11 | 5 | 89 | 30 | 10 | 6 | 3 | 13 | 5 | 3 | 6 | 4 | 3 | 2 | 81:27:27:9:36: / 9:3:36:12:12:4 | >0.30 |

Since factor C is present in T. 8 and its allele in T. 11 (*vide* Appendix) and since C has no effect on seed-coat colour, segregation in flower colour is noticed in C. Ss. 11 to 5 in T. 8 × T. 11.

It is evident from the number of phenotypes that at least 4 pairs of factors should be concerned in these crosses and there should exist inter-action amongst some.   The occurrence of (1) $9:3:4$, (2) $27:9:12:12:4$, (3) $27:9:9:3:12:4$, (4) $12:3:1$ and (5) $36:9:3:9:3:3:1$ ratios in the $F_3$ families lends support to the latter statement.

It has been proved in previous subsections that T. 8 differs from strain 493 in possessing $F^r$ and the alleles of factors B and $T^2$, and that T. 13 differs from 493 in not having P factor [*vide* subsection (*b*) ii].   It follows, therefore, that T. 13 can be represented by $Bpf^rT^2$ and T. 8 by $bPF^rt^2$. When they are crossed, segregations for these four factors will occur.   If there is independent assortment amongst the four genes, there will be 16 genotypes with the frequencies shown in column 3 of the Table XII.

TABL. XII.

(*To show interactions of factors* B, P, $F^r$ *and* $T^2$.)

| Formula number | Genic composition | Frequency | Colour standard (C. S.) |
|---|---|---|---|
| 1 | B P $F^r$ $T^2$ | 81 | 11 |
| 2 | B P $F^r$ $t^2$ | 27 | 9 |
| 3 | B P $f^r$ $T^2$ | 27 | 10 |
| 4 | B p $F^r$ $T^2$ | 27 | 7 |
| 5 | b P $F^r$ $T^2$ | 27 | 4 |
| 6 | B P $f^r$ $t^2$ | 9 | 8 |
| 7 | B p $f^r$ $T^2$ | 9 | 7 |
| 8 | B p $F^r$ $t^2$ | 9 | 6 |
| 9 | b P $F^r$ $t^2$ | 9 | 2 |
| 10 | b p $F^r$ $T^2$ | 9 | 4 |
| 11 | b P $f^r$ $T^2$ | 9 | 3 |
| 12 | B p $f^r$ $t^2$ | 3 | 5 |
| 13 | b P $f^r$ $t^2$ | 3 | 1 |
| 14 | b p $F^r$ $t^2$ | 3 | 2 |
| 15 | b p $f^r$ $T^2$ | 3 | 3 |
| 16 | b p $f^r$ $t^2$ | 1 | 1 |

Now formula 7 is the constitution of T. 13 which is C. S. 7. It has been pointed out [*vide* subsection (*b*) v] that the C. Ss. 11, 10, 9, 8, 4, 3, 2 and 1 have respectively the genic formulæ given in Table VIII to which factor P being common to all the C. Ss. has to be added. They are then identical to the formulæ Nos. 1, 3, 2, 6, 5, 11, 9 and 13 respectively of the above table and these are shown in column 4. Formulæ Nos. 10, 14, 15 and 16 will respectively refer to the same C. Ss. as formulæ 5, 9, 11 and 13, in view of the fact that bp condition does not induce any separate effect on seed-coat colour [*vide* subsection (*b*) vii].

Three formulæ (Nos. 4, 8 and 12) are yet to be accounted for. A study of the nature of segregation in $F_3$ families derived from these colour standards suggests solution. Families from C. S. 7 segregate into 36 : 9 : 3 : 9 : 3 : 3 : 1 or 12 : 3 : 1 or 3 : 1 indicating thereby that they are heterozygous for 3 factors. Those from C. S. 6 give dihybrid and mono-hybrid ratios while progenies from C. S. 5 yield mono-hybrid ratios only. It is therefore evident that C. Ss. 6 and 5 should respectively contain two and one heterozygous factors. Of the three formulæ, No. 4 alone is capable of being impure for three factors and hence it should relate to C. S. 7. Formula 12 can give only single factor segregation and hence it belongs to C. S. 5. The remaining formula 8 should, therefore, represent C. S. 6. It is thus seen that the reduction in the number of phenotypes observed in the $F_2$ is brought about by the merging of genotypes in C. Ss. 7, 4, 3, 2 and 1.

It is seen now C. S. 7 consists of two genotypes with constitution $BpF^rT^2$ and $Bpf^rT^2$. This leads one to conclude that factor $F^r$ has no colour reaction in such genic backgrounds. It suggests that the individual or combined presence of factors B and $T^2$ in the absence of P suppresses the chromatic properties of factor $F^r$. That the presence of $T^2$ has no such effect is evident from the fact that C. S. 3 which contains $T^2$ is converted into C. S. 4 by the addition of $F^r$ (*vide* subsection iv). That the combined presence of B and $T^2$ is not also responsible for the suppression is clear from the fact that the addition of $F^r$ to C. S. 5 has not produced any change in seed colour in the formation of C. S. 6. Hence it is obvious that the factor B alone inhibits the chromatic effect of $F^r$.

It is easily seen now that the ratios 9 : 3 : 4, 27 : 9 : 12 : 12 : 4 and 27 : 9 : 9 : 3 : 12 : 4 are brought about by the non-effectiveness of bP on seed colour and that ratios 12 : 3 : 1 and 36 : 9 : 3 : 9 : 3 : 3 : 1 are caused by the masking effect of B on $F^r$ in Bp condition. The latter aspect will be discussed further in section (*c*).

<div align="center">

(ix)   Roods brown (C. S. 12) $\underline{BPfrT^1T^2}$

×

Pale ochraceous Salmon (C. S. 2) $bPF\underline{rt^1t^2}$.

</div>

Two crosses were studied.   $F_1$ was of new colour—Vandyke brown. Six new colour standards which could not be brought under any of the thirteen C. Ss. described here were obtained in $F_2$.   Unfortunately, the populations even in $F_3$ generations turned out to be very small.   It was difficult to determine the genic constitution of the phenotypes.   Further work is under way.   It may, however, be stated from the nature of segregation that C. S. 13 is a composite of all the five factors B, P, $F^r$, $T^1$ and $T^2$.

(c)   *Colour factors and seed shape.*—Segregations for seed shape were first noticed in the progenies of T. 10 × T. 8.   Parent T. 10 had irregular shaped seeds while those of T. 8 were round.   In the $F_2$, C. Ss. 4 and 2 were round and C. Ss. 3 and 1 were irregular. It has been shown [*vide* subsection (b) iv] that the former two C. Ss. had only factor $F^r$ in common while the latter were similar in not containing $F^r$.   Since there are only two colour factors $F^r$ and $T^2$ at work in that cross and since seeds are round when $F^r$ is present, it is plain that $F^r$, besides changing the seed colour, causes round shape to seeds.

Similar segregations were also observed in the progenies of 493 × T. 8 [*vide* subsection (b) v].   Some of the round seeded $F_3$ families gave rise to both round and irregular seeds while irregular seeded families always bred true to that shape.

When the round seeded T. 8 was crossed with another round seeded type T. 13, complications were found to occur.   Types with irregular shape (C. Ss. 1, 3, 8 and 10)   appeared in the progenies indicating that $F^r$ was absent in one of the parents.   Since it is known already that $F^r$ is present in T. 8, it is clear that T. 13 lacks it, and contains another factor controlling the shape of the seeds.   Again, C. S. 5 which also does not contain $F^r$ but contains only B has round seeds.   It is deduced that factor B which is also present in T. 13 is responsible for the round seeds.   But in C. S. 8 where B is present with P, the seeds are irregular.   Such a condition indicates that B gives round shape to seeds only when it is not in association with P.

There are thus two factors responsible for roundness of seeds.   Factor $F^r$ is the common factor influencing shape but it becomes hypostatic to B when the latter is not associated with P.   Factor B too imparts round form to seeds in Bp condition.

(d)   *Colour factors and seed surface.*—Seeds in C. Ss. 2 and 4 have a puckered surface when compared with C. Ss. 1 and 3.   It cannot be said

that the peculiar surface is purely physical consequent on the transforma-
tion of the irregular to round shape.  For in C. S. 5 where the seeds are
round and $F^r$ is absent, the puckering is not perceptible.  As the former
standards differ from the latter only in factor $F^r$, it is taken that $F^r$ is res-
ponsible for such an expression.  But the above characteristic is not clearly
discernible in C. Ss. 13, 11, 9 and 7 although they too contain $F^r$.  It would
therefore appear that the puckering property of $F^r$ is affected when it acts
in co-operation with BP or $BT^2$.

In C. S. 6 the surface is more prominently depressed along the veins
than in C. S. 5.  In fact, it is this feature that distinguishes C. S. 6 from
C. S. 5.  Since the former differs from the latter only in $F^r$ it would seem
that $F^r$ causes a different effect on the surface in the presence of B alone.

(e)  *Colour factors and seed size.*—Seeds of T.11 and T.13 are consider-
ably smaller than those of other pure lines studied.  It was at first thought
that they were controlled by separate size factors, since bigger seeded types
were obtained from smaller seeded families in some of the hybrid progenies.
The examination of the progenies of T. 8 × T. 13 indicated, however, that
the small size similar to T.13 obtained in C. Ss. 5, 6 and 7 could easily be
explained with the aid of the interacting colour factors only.  The average
seed of each colour standard is given in Table XIII.

TABLE XIII.

| Colour standard (C. S.) | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Average weight per seed in mgs. | 144 | 152 | 128 | 136 | 63 | 50 | 63 | 163 | 141 | 110 | 128 |

It is seen that the low weights occur only in C. Ss. 7, 6 and 5 which has been
further confirmed by $F_4$ data.  Since these three represent the combination
of Bp with other factors it is deduced that the reduction in weight noticed
in C. Ss. 5, 6 and 7 is caused by the factor B when it is not in association
with  P.

### 7.  Discussion.

The above investigations have revealed that six factors B, C, P, $T^1$,
$T^2$ and $F^r$ severally or in co-operation, control the production of certain
flower and seed-coat colours.  Of these factors B, C and P alone influence
flower colour.  Their inter-relationship has been discussed already [*vide*
subsection (*a*)].

In the case of thirteen colour standards formed for the classification
of seed colour, the differences can satisfactorily be explained with five pairs

of factors, *viz.*, Bb, Pp, $F^r f^r$, $T^1 t^1$ and $T^2 t^2$. Factor C has no effect. The all recessive condition is represented by C. S. 1. How the different C. Ss. are formed from the basic C. S. 1 is given in Table II (*a*).

Shaw (1929) mentions orange as the fundamental colour of grams. In the numerous progenies of the several Deshi types studied at Coimbatore, orange colour has not appeared so far. It is only when Kabuli types are used as parents orange seeds are secured. Dixit (1932) has proved that Kabuli types have 8 pairs of chromosomes while Deshi have only 7. It is likely, therefore, that the gene for orange might have come from the additional chromosome pair present in the Kabuli parent used. Shaw further states that red seed colour is correlated with pink flower colour. In the present investigations red seeds were also obtained from white flowered types as in the cross between T. 8 × T. 11 [*vide* subsection (*b*) viii].

It is surprising to note that none of the six factors appear to be linked with one another. All of them display, however, complete dominance though only four show interaction in development. Some possess pleiotropic effects which vary with the nature of factors they co-operate with.

Incidentally, it may be mentioned that the nature of the flower colouration could correctly be forecasted from the colour of the stem and pedicel. When the stems and pedicels are green or white, the petals are green or white. If the stems are bluish pink, the petals are blue. In the pink types the colouration of the stems gets intensified. Such an early indication of the probable colour of the petal has been very helpful in classifying the plants in families susceptible to wilt.

### 8. *Acknowledgment.*

### 9. *Summary.*

Modes of inheritance in three types of flower colours and thirteen types of seed-coat colours in gram (*Cicer arietinum*) were studied in crosses between pure lines isolated at Pusa and Coimbatore.

It is demonstrated that the production of pink, blue and white petals is controlled by three factors C, B and P, of which C and B are complementary and P is supplementary to B. When all the three factors are in

combination, the flowers are pink. If B and C alone are present, blue flowers are produced. In all other combinations, the petals are white.

In the case of seed colours it has been found that factor C has no effect, and that the five factors Bb, Pp, $T^1t^1$, $T^2t^2$ and $F^rf^r$ alone account for the existence of various shades among the thirteen grades. None of them were found to be linked. All of them showed dominance. Factors P and $T^1$ showed supplementary type of interaction in development, while factor $F^r$ was hypostatic to B. Factors B and $F^r$ exhibited pleiotropic effects on plant characters.

Factor B imparts, by itself, dark olive buff colour to the seed-coat. Factor P is inactive by itself but causes considerable changes in the pheno-types in the presence of B. Genes $T^1$ and $T^2$ affect only the seed-coat colours. $T^1$ is inoperative unless it is in association with P. It then darkens the colour pattern. $T^2$ also has the same reaction but its expression is influenced by the nature of the genic background. Factor $F^r$ has no chromatic effect in the presence of B but dilutes the pigmentation when it is not in company with B. It makes the seed-coat darker if B and P are conjointly present.

The shape of the seeds are also affected by some of these factors. $F^r$ converts irregular shaped seed into round. This property is, however, masked by B when in association with the recessive gene p. Factor B also produces round seeds but loses this quality in the BP condition.

B factor, in addition, influences the size of the seeds. When it occurs alone without P, the seeds are reduced in size considerably, but they are restored to normal weight when P is added to B.

The surface of the seeds gets puckered by the action of $F^r$. But this effect is very much reduced when it is in association with B and P, or B and $T^2$.

TABLE XIV.

| Nature of the cross | Petal colour in $F_1$ | Number of families | Total number of plants | Actual numbers obtained in $F_2$ | | | Expected ratio | Value of P |
|---|---|---|---|---|---|---|---|---|
| | | | | Pink | Blue | White | | |
| T. 8  × T. 11 | Pink | 17 | 525 | 211 | 77 | 237 | 29 : 9 : 28 | > 0·50 |
| T. 8  × T. 12 | Pink | 7 | 84 | 48 | | 36 | 9 : 0 : 7 | > 0·80 |
| T. 8  × T. 13 | Pink | 7 | 350 | 197 | 62 | 91 | 9 : 3 : 4 | > 0·80 |
| T. 11 × T. 12 | White | 10 | 558 | | | 558 | | |
| T. 11 × T. 13 | Blue | 5 | 131 | | 99 | 32 | 0 : 3 : 1 | > 0·80 |
| T. 12 × T. 13 | Pink | 1 | 48 | 25 | 9 | 14 | 9 : 3 : 4 | > 0·80 |

It is known that the genic constitution of T.13 for flower colour is CBp. Since the cross between T. 13 and T. 11 gave only a blue $F_1$ and segregated in $F_2$ into 3 blues : 1 white, it is obvious that T. 11 contains the recessive gene p as T. 13. Since the $F_1$s of T. 13 × T. 8 and T. 13 × T. 12 were pink flowered, T. 8 and T. 12 should have the factor P. The production of dihybrid ratio of 9 : 3 : 4 in $F_2$s of these crosses indicates that T. 8 and T. 12 should contain one more factor besides P. The fact that the mating between T. 8 and T.12 has given 9 : 7 ratio in the $F_2$ points out that each of them contains a factor with complementary effect. It is known already that B and C are the two factors that possess this quality in the production of flower colour. If T. 8 has B, T. 12 will have its complementary gene C and *vice versa*. Since T. 8 × T. 11 gives a trihybrid ratio and since it is seen that T. 8 has only 2 dominant genes for flower colour, it follows that T. 11 contains the third gene. As T. 12 is shown to contain a gene complimentary to one of the genes in T. 8, it is inferred that gene in T. 11 must be the same as in T. 12. This is confirmed by the observation that $F_2$ progenies of T. 11 × T. 12 are all white flowered. It has been proved already that T. 11 lacks P while T. 12 has it. The probable genetic constitution of the petal colour in these three will correspondingly be one of the following two:

|   T. 8   |   T. 11   |   T. 12   |
|----------|-----------|-----------|
| CCbbPP   | ccBBpp    | ccBBPP or |
| ccBBPP   | CCbbpp    | CCbbPP    |

It is not possible to say from the available data which of the two is more appropriate. For the sake of uniformity and simplicity, the first is taken in the present studies.

It has been ascertained by suitable crossings T. 10 has similar genic constitution for flower colour as T. 8 (*vide* Table XV).

TABLE XV.

| Parents | Petal colour in $F_1$ | Total number of plants | Actual numbers obtained in $F_2$ | | | *Expected ratio* | Value of P |
|---------|------------------------|------------------------|------|------|-------|------------------|------------|
|         |                        |                        | Pink | Blue | White |                  |            |
| T. 10 × T. 8 | White | 314 |     |    | 314 |        |         |
| T. 10 × T. 12 | Pink | 199 | 116 |    | 83 | 9 : 0 : 7 | > 0·50 |
| T. 10 × T. 13 | Pink | 160 | 94 | 29 | 37 | 9 : 3 : 4 | > 0·80 |

It has been found that T.11 has the same genic formulæ as T.13 for seed colour except for the recessive gene c.

| Parents | Colour of the parent | Number of families studied | Total number of plants | Actual number in $F_2$ | | *Expected ratio* | Value of P |
|---------|----------------------|----------------------------|------------------------|----------------------|----------------------|------------------|------------|
| | | | | Blue petal C. S. 7 | White petal C. S. 7 | | |
| T. 13 × T. 11 | C. S. 7 | 5 | 103 | 77 | 26 | *9 : 3* | >0·90 |

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## 10. *Appendix.*

*Genic constitution of the white flower colour in T. 8, T. 11 and T. 12.*—Three white flowered types T. 8, T. 11 and T. 12 were crossed between themselves and with the blue flowered type T. 13. The nature of segregations are given in Table XIV.

V. *Ramanatha Ayyar and*
*R. Balasubramanian.*

*Proc. Ind. Acad. Sci., B, vol. IV, Pl. I.*



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# A NEW SPECIES OF THE GENUS *PARORCHIS* FROM *TOTANUS HYPOLEUCOS*, WITH CERTAIN REMARKS ON THE FAMILY ECHINOSTOMIDAE.

BY MAKUND BEHARI LAL, M.Sc.

*(From the Department of Zoology, Lucknow University.)*

BRAUN (1902) described a trematode *Distomum pittacium* from *Tringa interpres*. Four years later, Nicoll (1906) described an apparently similar trematode as *Zeugorchis acanthus* from the bursa fabricii of the herring gull, *Larus argentatus*. Nicoll's original description was based on two preserved specimens but subsequently (1907) he obtained live specimens from the same host and also from the rectum of the common gull, *Larus canus*; and redescribed them as *Parorchis acanthus*, *Zeugorchis* being pre-occupied. He further transferred *Distomum pittacium*\* Braun to the genus *Parorchis*, naming it *Parorchis pittacium* (syn. *Distomum pittacium* Braun) on the assumption that the absence of the spines and the circum-oral collar in *Parorchis pittacium* (syn. *Distomum pittacium*) is due to Braun's incomplete observations on a single badly preserved specimen from the Vienna Museum collections. Linton (1914) described another species of *Parorchis* from the cloaca of the herring gull, *Larus argentatus* and named it *Parorchis avitus*. Nicoll doubted the specific identity of this species in a letter to Linton who in 1928 definitely established his form as a new species.

During the course of my studies on the trematode parasites of Birds in Lucknow, I have obtained a number of parasites from the cloaca of the common Summer Snipe, *Totanus hypoleucos* and these are being described here as a new species.

## *Parorchis snipis* N. Sp.

The worms showed great activity when kept in normal salt solution and appeared white, being roughly elliptical in shape. The length of the trematode is 2·58 mm. and its greatest breadth which lies just behind the level of the vesicula seminalis is 1·1 mm. The head is inconspicuously marked off from the rest of the body and at the level of the oral sucker is a raised ridge-like prominence forming a kind of collar round it. The collar is incomplete on the ventral side where its ends are directed medially upwards.

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\* The author is not in a position to express any opinion at present regarding the position of *Distomum pittacium*.

There is a single row of spines on the collar.  These spines, except for four pairs which lie at the lateral margin and are the largest (measuring ·025 mm. long), are similar to those of the neighbouring body-wall.  The general ventral surface upto the level of the ventral sucker is also beset with small scale-like spines.
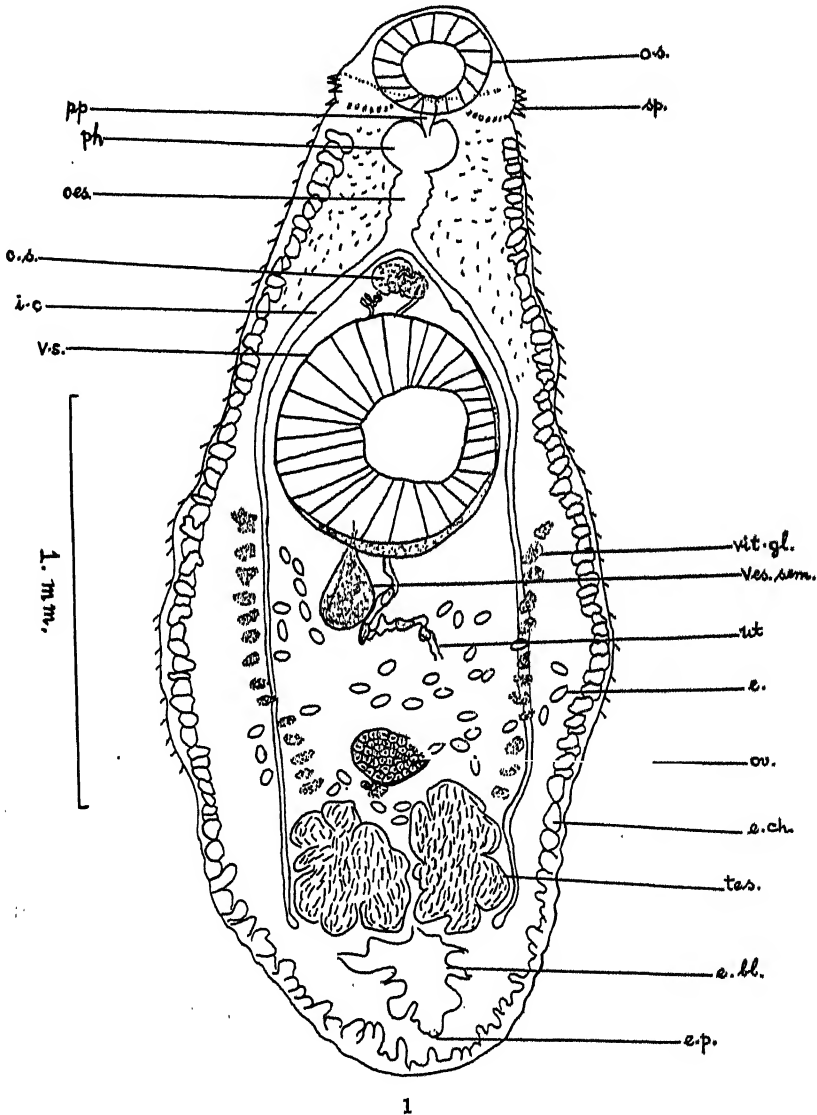


FIG. 1.—*Parorchis snipis* n. sp.  Ventral view showing the disposition of the internal organs.

The oral sucker is sub-ventral and strongly muscular.  It measures ·24 mm. × ·27 mm. in diameters.  The ventral sucker, which lies at a

distance of ·745 mm. from the anterior end of the animal, is also very power-
ful with thick muscular walls and measures ·58 mm. × ·55 mm. in —
diameters.

The oral sucker leads into a small prepharynx, ·07 mm. long, the posterior
part of which is, rather, wedged into the pharynx which is a bulbous ovoid
structure, thick-walled and measures ·12 mm. × ·18 mm. The œsophagus,
arising at the base of the pharynx, runs for a distance of ·19 mm. before
dividing into the two intestinal cæca. The œsophagus is wide and saccular,
its width being ·095 mm. The intestinal bifurcation takes place at a distance
of ·6 mm. from the anterior end and about ·145 mm. in front of the ventral
sucker. The intestinal cæca pass round the ventral sucker and reach upto
the hinder end of the testes where they terminate in slightly dilated ends.

The excretory system is peculiar and resembles that of *Parorchis
acanthus*. The excretory bladder which lies at the posterior end behind the
testes, is a sac-like structure with lateral diverticula and measures ·26 mm.
long and ·3 mm. in the region of the longest diverticulum. It opens out at
the excretory pore which lies dorsal to it. The two excretory ducts on the
lateral sides form anastomosing chambers as in *Parorchis acanthus*.
Anteriorly these excretory chambers extend upto the base of the head and
posteriorly those of the two sides unite to form a continuous chain.

The male reproductive organs consist of two testes placed side by side,
a seminal vesicle, a cirrus pouch and the cirrus. The testes are 7–8 lobed
and are situated, at about ·35 mm. from the posterior end, just in front of
the excretory bladder. The right testis is broader than the left, the latter
is slightly longer than the former. The right testis measures ·35 mm. × ·27
mm. and the left ·36 mm. × ·225 mm. Both the testes lie intercæcally
almost filling up the intercæcal space near the termination of the cæca.
The vesicula seminalis is a large pear-shaped body lying behind the ventral
sucker and measures ·2 mm. × ·13 mm. It has got a broad body and a
thin neck which runs dorsal to ventral sucker and terminates in a greatly
coiled duct beyond it communicating with the cirrus-sac. The latter is
·09 mm. long and lies just behind the intestinal bifurcation by the side of the
genital atrium. The prostate gland-cells are scattered in the basal portion
of the cirrus-sac.

The female genital organs consist of an ovary, a small receptaculum
seminis, the öotype complex and the uterus with terminal metraterm. The
ovary, which lies at a distance of ·065 mm. in front of the testes, is a small
ovoid body measuring ·185 mm. × ·14 mm. Just behind it lies the recepta-
culum seminis, measuring ·035 mm. × ·032 mm. and the shell-gland sur-
rounding the öotype. The uterus, arising from the left side of the öotype,

goes backwards and after forming a U-shaped loop runs on the right of the ovary and later forms transverse loops in front of it. Near its distal end
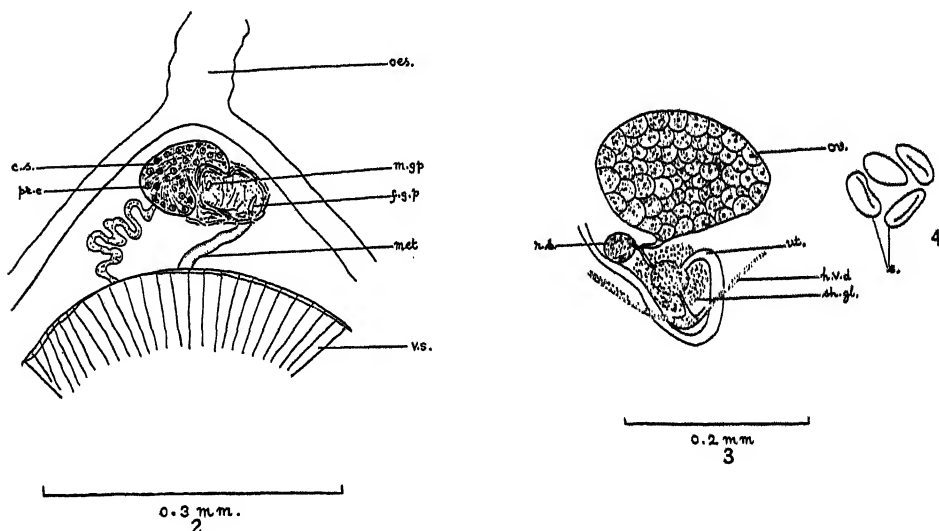


FIG. 2.—*Parorchis snipis* n. sp., showing the cirrus sac, and male and female genital openings.

FIG. 3.—*Parorchis snipis* n. sp., showing ovary, receptaculum seminis and öotype complex.

FIG. 4.—*Parorchis snipis* n. sp., showing eggs.

it touches the vesicula seminalis and runs dorsal to the ventral sucker ending in a small metraterm. The metraterm lies on the left side in front of the ventral sucker and opens into the genital atrium by the side of the male genital aperture. The eggs are arranged in a single row inside the uterus and measure ·05 — ·06 mm. × ·025 mm. The eggs show complete segmentation inside the uterus.

The vitelline glands are about a dozen distinct follicles on each side and are confined between the ventral sucker and the testes. They are mostly extracæcal except a few follicles near the testes which cross the intestinal cæca and lie intercæcally. The lateral horizontal ducts of the two sides run in front of the testes to meet the öotype.

To sum up, the species may be characterised by the following features :—

  1. Distomes, with a distinct head region possessing a raised collar-like ridge beset with spines of which four lateral pairs are large.

  2. A short prepharynx, bulbous pharynx and a wide saccular œsophagus present.

  3. Excretory system characteristic, with a sac-like excretory bladder and chambered lateral excretory ducts.

4.   Two testes, connubial, lobed, intercæcal ; vesicula seminalis pear-shaped behind the ventral sucker ; cirrus sac present with  cirrus.

5.   Ovary pre-testicular ; shell-gland post-ovarial ; receptaculum seminis present ; eggs small in a single row inside the uterus showing segmentation ; uterus confined between the testes and ventral sucker and mostly intercæcal.

6.   The male and female genital pores lie side by side in the genital atrium behind the intestinal bifurcation.

7.   The vitelline glands consist of a dozen distinct follicles, mostly extracæcal except a few which are intercæcal  near the testes. The lateral horizontal vitelline ducts are pre-testicular.

*Discussion.*

The genus *Parorchis* is known to possess two† species, *viz.*, *Parorchis acanthus* and *Parorchis avitus*. *Parorchis pittacium* (syn. *Distomum pittacium* Braun) is regarded by Linton (1928) as almost identical with *Parorchis avitus* except for a collar and spines which he thinks have been overlooked by Braun.   The form described in the present paper differs from *Parorchis acanthus* in possessing a smaller œsophagus, in having the male and female genital openings behind the intestinal bifurcation and in the post-ovarial position of the shell-gland.   From *Parorchis avitus* it differs in being oviparous, in the less extensive uterine convolutions, in having a single row of eggs in the uterus and in possessing a receptaculum seminis.   It differs from both in having four pairs of large collar spines, in the pre-testicular position of the receptaculum seminis, in the lateral postion of the cirrus-sac, in having separate male and female genital openings, in the limitation of vesicula seminalis behind the ventral sucker and in possessing a weak ridge-like projection to form the collar.   These characters appear to be sufficient to justify the creation of a new species for the form described in the present communication and the name *Parorchis snipis* is given.

*Systematic Position of the Genus* Parorchis.

The genus *Parorchis* was included under the family Philophthalmidæ by Nicoll (1907).   Odhner (1913) and Poche (1925) put it under Echinostomidæ.   Fuhrmann (1928) and Sprehn (1932) consider it as an isolated genus under Echinostomidæ.   There is no doubt that the genus *Parorchis* is an Echinostome as even the cercaria stage of *Parorchis* shows a circum-oral collar and spines.   There are, however, some important differences between the true Echinostomes and *Parorchis*. The presence of a receptaculum seminis,

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† *Parorchis pittacium* not included.

the testes lying side by side intercæcally and the peculiar nature and distribu-
tion of the vitellaria between the ventral sucker and the testes, as well as the
chambered lateral excretory vessels are some of the fundamental features
of differences from all the existing sub-families of Echinostomidæ.   It has,
therefore, been considered advisable to create a new sub-family Parorchinæ
on these characters for the reception of the genus *Parorchis*.

*Characters of the sub-family Parorchinæ* N. Sp.—Echinostomidæ, with
typical excretory chambers along the lateral margins of the animal, excretory
bladder sac-like with the excretory pore on its dorsal surface.   Two testes,
connubial, lobed, intercæcal at the posterior end of the body ;   cirrus-sac
present with a cirrus ; prostate gland-cells present ; vesicula seminalis pear-
shaped mostly behind ventral sucker ; receptaculum seminis always present
except in *Parorchis avitus*. Vitelline glands, follicular, confined between
ventral sucker and testes, extracæcal for the most part but become inter-
cæcal towards the testes.   Uterine coils generally between ventral sucker
and testes, sometimes more extensive.   Forms oviparous or viviparous.

Type Genus *Parorchis*.

### Observations on the Evolution of the Echinostomes.

The study of the genus *Parorchis* has revealed three important features :—

1. *Transition from Ovipary to Vivipary*.—The three species of the
genus *Parorchis* show a series of gradations between ovipary and vivipary.
*Parorchis snipis* n.sp. is oviparous but the eggs show complete segmentation
while still inside the uterus.   The next stage is that of *Parorchis acanthus*
where the eggs inside the uterus show fully formed miracidia.   Although
this species is oviparous in the strict sense, the miracidia are set free soon
after the shedding of the eggs.   A further advance is shown by Linton (1914)
in *Parorchis avitus* where not only does the egg-shell burst open inside the
uterus but live miracidia are set free from the genital aperture, a pheno-
menon of rare occurrence in trematodes.   Even small rediæ are seen inside
the fully formed miracidia in this species.

2. *Evolution of the Collar*.—A gradual progressive development of the
collar is also met with in the three species of *Parorchis*.   In *Parorchis snipis*
the collar is weak in the form of merely a raised ridge with spines very
much like the spines on the general surface of the body.   The collar is
better developed in *Parorchis acanthus* and possesses larger spines.   In
*Parorchis avitus*, not only is the collar very well developed but is further
strengthened by powerful muscles and the spines are also supplied by
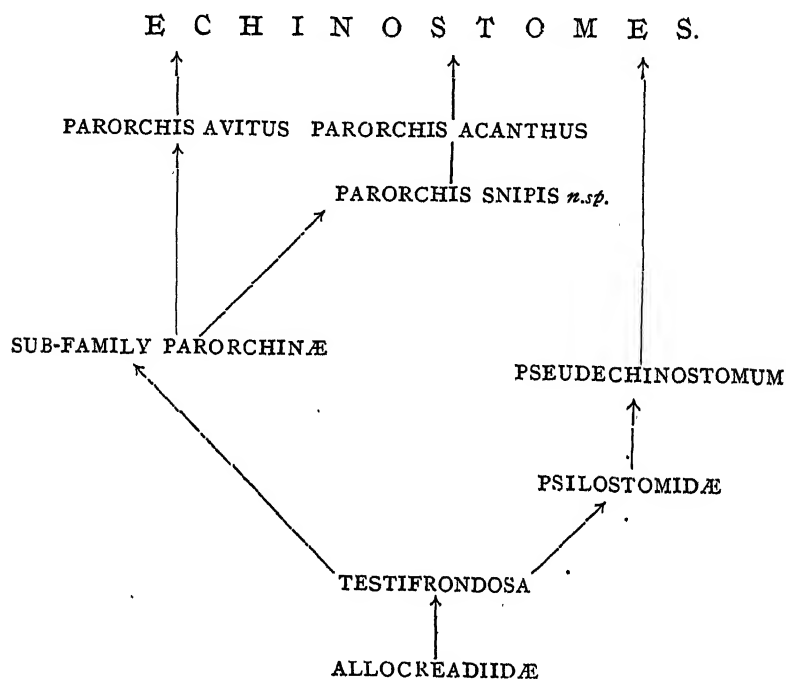oblique muscles.

3.   *Retrogression of the Receptaculum Seminis.*—That a retrogression and not progression has taken place so far as the receptaculum seminis is concerned, is proved by the fact that the oviparous species of *Parorchis* viz., *Parorchis snipis* and *Parorchis acanthus* possess a receptaculum seminis but that is lost in the viviparous form, *Parorchis avitus.*

These three important features show a correlation with each other and throw some light on the evolution of the family Echinostomidæ.   It is an admitted fact that vivipary is a stage of higher development than ovipary and thus it would be natural to expect that the highest type of Echinostome organisation would be met with in those forms which are viviparous. *Parorchis snipis* which is oviparous has a weak collar and a receptaculum seminis. *Parorchis acanthus,* showing fully developed miracidia in the pre-natal eggs, has a better developed collar and also a receptaculum seminis. *Parorchis avitus* which is, so to say, viviparous has an extremely well-developed collar with strong muscles and does not possess a receptaculum seminis.

These observations lead us to the conclusion that the collar and the spines of the Echinostomes are secondary developments and have arisen from a primary stage where these structures are absent or rudimentary. A further proof of this is obtained in *Pseudechinostomum* which has all the characters of Psilostomidæ except for a rudimentary collar and shows the possible transition from collar-less forms in Psilostomidæ to collared forms in Echinostomidæ.   Side by side has taken place a retrogression of the receptaculum seminis as seen in the genus *Parorchis* and here, too, we get another proof from the study of the families Psilostomidæ and Allocreadiidæ. The Allocreadiidæ are characterised by the presence of a large receptaculum seminis which is entirely absent in the Psilostomidæ.   It is, however, present in the genus *Testifrondosa* Bhalerao, and shows a possible evolution of Psilostomidæ from Allocreadiidæ, as suggested by Thapar and Lal (1935). It further gives us a clue to the origin of the sub-family Parorchinæ where we get a receptaculum seminis and represents a line in the evolution of the Echinostomes.

The recurrence of a receptaculum seminis in some of the Echinostomes could not be satisfactorily explained so far, but a study of the species of *Parorchis* has thrown a hint on this important point for consideration.   The species *Parorchis snipis* and *Parorchis acanthus* possess a receptaculum seminis while in the more highly evolved species *Parorchis avitus* it is absent.   Both the groups of species show a collar and spines and have given rise to Echinostomes.   Those forms which have arisen as an offshoot from the main stem from ancestors like *Parorchis snipis* and *Parorchis acanthus,* possess a receptaculum seminis but those true Echinostomes which have originated from

forms like *Parorchis avitus* in the proper course entirely lost it. It is, therefore, evident that the evolution of Echinostomes has proceeded along several convergent lines and that the family Echinostomidæ has a polyphyletic origin, as is indicated in the following Table :—

E C H I N O S T O M E S.

PARORCHIS AVITUS  PARORCHIS ACANTHUS

PARORCHIS SNIPIS *n.sp.*

SUB-FAMILY PARORCHINÆ

PSEUDECHINOSTOMUM

PSILOSTOMIDÆ

TESTIFRONDOSA

ALLOCREADIIDÆ

In conclusion, I wish to record my sincere thanks to Dr. G. S. Thapar for his kind guidance and suggestions during the course of this work.

LIST OF ABBREVIATIONS USED IN THE FIGURES.

| | | | | | |
|---|---|---|---|---|---|
| *c.s.* | .. | .. Cirrus sac. | *o.s.* | .. | .. Oral sucker. |
| *col.* | .. | .. Collar. | *ov.* | .. | .. Ovary. |
| *e.* | .. | .. Eggs. | *ph.* | .. | .. Pharynx. |
| *e.bl.* | .. | .. Excretory bladder. | *pp.* | .. | .. Prepharynx. |
| *e.ch.* | .. | .. Excretory chamber. | *pr.c.* | .. | .. Prostate gland-cells. |
| *e.p.* | .. | .. Excretory pore. | *r.s.* | .. | .. Receptaculum seminis. |
| *f.g.p.* | .. | .. Female genital pore. | *sh.gl.* | .. | .. Shell-gland. |
| *gen.atr.* | .. | .. Genital atrium. | *sp.* | .. | .. Spines. |
| *h.v.d.* | .. | .. Horizontal vitelline duct. | *tes.* | .. | .. Testis. |
| *i.c.* | .. | .. Intestinal cæca. | *ut.* | .. | .. Uterus. |
| *m.g.p.* | .. | .. Male genital pore. | *ves.sem.* | ... | .. Vesicula seminalis |
| *met.* | .. | .. Metraterm. | *vit.gl.* | ..., | .. Vitelline gland. |
| *oes.* | .. | .. Œsophagus. | *v.s.* | .. | .. Ventral sucker. |

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# OCCURRENCE AND DISTRIBUTION OF THE FRESHWATER ALGAE OF NORTH INDIA.

BY M. S. RANDHAWA, M.SC., I.C.S.

*(Saharanpur)*

I MADE a collection of the Panjab Freshwater Algæ from July 1929 to April 1930, and February 1931 to October 1931, from Lahore, Jullunder and Hoshiarpur districts of the Panjab. Then I had another opportunity of making a collection of the freshwater algæ in Saharanpur district of the United Provinces from December 1934 to January 1936. In all about 420 samples were collected comprising 122 species which have been worked out and these include two new genera and sixteen new species. Hoshiarpur and Jullunder districts are situated between the Sutlej and Beas rivers, and contain two perennial streams the Siah and the Sufed Baeens. These two districts provide unique opportunities for algal collections, and it is no exaggeration if I call them an Algalogist's Paradise. Hoshiarpur and Saharanpur districts contain a chain of ponds in the submontane areas, as well as swamps which are called 'Chhambs' locally. Saharanpur district is situated between the Ganges on the east and the Jumna on the west with two big canals, and numerous small streams meandering across the district. The swamps in these districts are annually replenished by rain-water from the hills brought by the 'choes,' which are seasonal torrential rivers which sweep down the plains during the rainy season. Geographically these districts are very much similar being bound by the Siwalik range in the North, and have practically the same sort of climatic conditions.

There are numerous big tanks also made by religiously- or charitably-disposed people which afford ample opportunities for algal collections. In addition there are ponds which are found in practically every village for the use of cattle, and these are also very interesting from the algal point of view. The ponds and ditches found on both sides of the railway lines in many districts are also full of algæ during and after the rainy season.

*Climatic Conditions.*—Hoshiarpur is a submontane district lying between 30°·59 and 32°·5 N and 73°·30 and 76°·38 E. The annual average rainfall is 36″, of which 30″ fall in the summer months and 6″ in the winter months. Jullunder and Lahore resemble each other very much and as

compared with Hoshiarpur they are more dry and hot. The hottest months are May and June, with a mean maximum temperature of 106° F., the highest temperature recorded being 120° F. The coldest months are December and January, with a mean minimum temperature of 40° F. The rainfall seldom exceeds 25″ per annum. Saharanpur resembles Hoshiarpur in nearly every way, the only difference being that the rainfall is greater in Saharanpur.

*Occurrence and Reproduction of Freshwater Algæ.*—Five main groups of algæ, *viz.*, Diatoms, Myxophyceæ, Isokontæ, Heterokontæ and Rhodophyceæ, have been studied so far by Mr. Abdul Majeed, Dr. S.L. Ghose and the author in Northern India. Diatoms are very abundant during the winter months from the middle of November to the end of February, and my own observations fully corroborate the conclusions reached by Mr. Abdul Majeed in his investigations of the Panjab Diatoms. Forms like *Navicula, Cyclotella, Surirella, Synedra* and *Nitzschia* are found in large numbers in the moist soil of fields after rains and in the drying sides of ponds and ditches. *Synedra, Navicula, Cyclotella, Cocconeis* and *Gomphonema* are also found in large numbers on the moist soil of fields after rains and on the drying sides of ponds and ditches. *Synedra, Navicula, Cyclotella, Cocconeis* and *Gomphonema* are also found in large numbers in stagnant or slowly-flowing sheets of water, free-floating, or attached to the rotting branches of water plants.

Myxophyceæ are met all the year round, but are very abundant after the close of the rainy season, in the months of October and November. Members of Myxophyceæ are both subaerial as well as aquatic, and in the latter case are found more commonly in stagnant sheets of water. Our knowledge of this group of algæ is mainly based on the work of Dr. S. L. Ghose. According to Dr. Ghose the Myxophyceæ in Lahore show great vegetative activity between August and February, and the fruiting season is from February to April. The study of spore-bearing forms like *Anabæna, Rivularia, Aulosira* and *Nodularia* is very interesting from this point of view. According to Dr. Ghose, *Anabæna variabilis* and *Rivularia natans* produce spores in the months of March and April. My own observations show that forms like *Anabæna cylindrica, Anabæna moniliforme, Anabænothrix epiphytica* and *Nodularia spumigena* produce numerous spores in the months of February and March. As I have shown in my paper on " Periodicity in the Reproduction of Freshwater Algæ," that the spore-bearing Green Algæ, like *Spirogyra, Zygnema, Ghosella, Sphæroplea* and *Oedogonium* produce huge crops of Zygospores and Oospores in March and April,[10] the spore-bearing Myxophyceæ like the species mentioned above,

also, do not lag behind in this respect. In fact, these Myxophyceæ are as well prepared to meet the drought of May, June and July in the form of thick-walled spores, as the Green Algæ.

I have already dealt at great length in a separate paper with the periodicity shown by the spore-bearing Green Algæ in their reproduction.[10] However, forms which multiply vegetatively by fragmentation, and zoospores, continue their cycle of reproduction intermittently. These algæ are found in artificial reservoirs of water, and perennial streams, and show a great luxuriance in growth from October to March.

*Ecological Survey of the Freshwater Algæ of Northern India.*—The following is in brief an ecological survey of the algæ of Northern India, which I have come across during my investigations.

*I. Subaerial Associations.*—Under this heading we shall deal with algæ which grow upon soil, in the form of patches, or in some cases in the form of mats. Subaerial forms also include algæ growing upon pieces of moist timber and walls of houses. So we may divide the subaerial associations into two main groups ; firstly, the soil algæ and secondly the algæ growing on wood and walls.

*A. Soil Algæ.*—The group of soil algæ includes three kinds of formations in this country.

1. Vaucheria *Community.*—This is equivalent to *Zygogonium ericetorum* formation of Europe. From the beginning of December to the last week of February, *Vaucheria sessilis* and *V. geminata* are seen covering large areas in lawns and grassy fields, in the form of bright-green felt-like mats. Oogonia and antheridia begin to appear in the first week of January, and by the last week of February most of the filaments become fertile. It is curious that *Vaucheria sessilis* collected from ponds at about the same time, as from the lawns, proved to be more fertile, each filament being loaded with huge crops of oogonia and antheridia, while in the case of terrestrial specimens, very few sex organs were seen.

2. Botrydium-Protosiphon *Community.*—Usually *Botrydium* and *Protosiphon* occur together on the sides of drying ponds after the close of the rainy season. In fields which are left fallow, one may quite often see almost pure formations of *Protosiphon botryoides*, in the month of November after rains. Cyst-formation takes place in a week and then the alga disappears. Bright green patches of *Protosiphon*, 2–8 yards in diameter, can be seen growing in the hollow parts of fields.

3. Cylinderospermum *Community.*—Black patches of *Cylinderospermum muscicola*, accompanied by a species of *Riccia*, occupy huge areas under

the shade of wheat plants in the month of March. Bacteria may also be seen in the mucous sheaths of this alga.

4. Campylonema *Community.—Campylonema Lahorense* appears in the form of woolly circular patches of a dark chocolate brown colour on the surface of lawns, and these patches expand laterally and form thick brownish sheets. Species of *Glæocapsa* and *Anabæna* may often be found intermingled with the filaments of *Campylonema Lahorense*.

*B. Timber Algæ and Wall Algæ.—*

1. Pleurococcus *Community.—*This consists of yellowish-green incrustation of *Pleurococcus vulgaris* which has a great liking for moist woodwork, lime-covered walls of houses, and earthen vessels like ' gharas ' and ' surahis '. After the rains this alga may be commonly seen on smooth pieces of wood, from which bark has been removed, and the walls of houses. This alga may be found throughout the year on the moist wood-work of Persian wheels, accompanied by Mosses.

2. *Bark Epiphytes.—*This group of algæ resembles in many features the formation discussed above, but differs in showing an almost exclusive preference for moist logs of wood and trunks of trees. *Aphanocapsa montana* appears in the form of light-blue-green patches on smooth trunks of trees from July to August, and as the trunks become drier, the alga becomes saphire-blue in colour. According to Ghose[5] *Phormidium truncicolum, Lyngbya truncicola* and *Tolypothrix campylonemoides,* may commonly be seen on the trunks of *Acacia modesta* in the form of a bluish-green layer, which becomes very slimy and conspicuous after the rains. In the wet season Hormogones are plentifully formed, and these produce mucilaginous sheaths which become thick, firm and coloured. When it becomes dry and warm, the stratum becomes thin and papery, and peels off the trunk of the tree in bits.

*II. Aquatic Associations.—*Under this heading we include all the algæ which are found growing in water, free-floating or attached to other water plants. This includes a large number of forms and we shall deal with only the commonest and most important species. According to their habitat, we divide this group into two main sub-groups, *viz.,* Algal Associations of Flowing Water and Algal Associations of Standing Water.

*A. Algal Associations of Flowing Water.—*This group may be further subdivided into two sub-groups, according to the velocity of the current of water in which these algæ grow.

1. *Algæ from Swiftly Running Water.—*This group of algæ is characterised by the possession of strong basal cells which very often secrete a

sort of cement-like material for fixation to other water plants, and require plenty of aeration. I found a number of Rhodophyceæ in the Siah Baeen near Dasuya in Hoshiarpur district, where it flows very rapidly. Attached to blades of rushes, in midcurrent, are found *Chantransia chalybea*, *Compsopogon*, *Batrachospermum moniliforme* and *Stigeoclonium variable*, in the months of August, September, October and November. In December, due to excessive cold perhaps, these algæ disappear. *Cladophora glomerata* also belongs to this group and may be seen in big tassels looking like fox-tails attached to fallen branches of water plants in most streams and canals. This group also includes a number of unicellular and colonial Myxophyceæ growing on stones, which are well worth investigating. By developing strong basal cells and on account of their liking for plenty of oxygen, these algæ exclude other competitors, and hold their own against all other algæ.

2. *Algæ from Slowly Running Streams.*—These algæ are also characterised by fondness for plenty of oxygen, but not so much as in the last mentioned group, and at the same time basal cells are not so well developed. As compared with the former one, it is a much more numerous group. *Cladophora glomerata*, *Mougeotia genuflexa*, *Draparnaldia plumosa*, *Chætomorpha aerea*, *Oedogonium* sp., and certain attached species of *Spirogyra*, are very characteristic of this group. Here we may also mention the interesting case of *Cladophora glomerata*, which grows on the shells of Gastropods in tanks in Shalamar Gardens, Lahore, and in the still water of the tanks secures its aeration through the help of these animals (Fig. 1). *Cladophora glomerata* also occurs in the reservoirs of wells fitted with Persian wheels, where the alga is constantly being aerated by the flow of water from the well. *Chætomorpha aerea* which generally occurs in freshwater streams may also be quite often seen growing under water-taps where there is a constant flow of water.

B. *Algal Associations of Stagnant Water.*—This group contains by far the largest number of algæ. This group may be divided into four subgroups according to their habit.

1. *Plankton forms.*—These are very tiny algæ, which are found floating in lakes, ponds and tanks. Some of these algæ have evolved special structures like bristles, flattening of the body, and the secretion of mucilage, for keeping afloat in water. Such bristles and flattened shape may be seen in *Pediastrum Boryanum*, *Scenedesmus obliquus* and *S. quadricauda*. Mucilage helps *Volvox aureus* and *Pandorina morum* in keeping afloat. *Microcystis aeruginosa* is simply flat in shape and has no other special structure. *Arthrospira spirulinoides* and *A. platensis* have a spiral
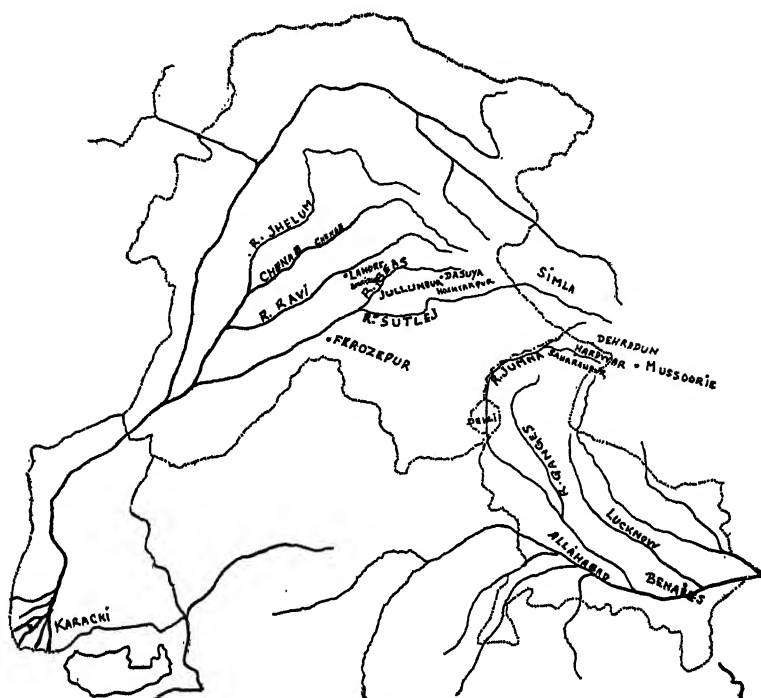
FIG. 1.

MAP OF NORTHERN INDIA.

Showing Places from where Collections of Algæ were made, 1929—1936.

like a cork-screw which helps the alga in keeping afloat. In this group of algæ we may also mention the different species of *Anabæna*, *Rivularia* and *Cylinderospermum* which are found free-floating in ponds and lakes though they have no special device as most of the Plankton forms have, excepting the secretion of mucilage. This group also comprises numerous Desmids which are practically untouched by any Algalogist in this country, and Diatoms which have partly worked out by Mr. Abdul Majeed.

2. *Benthic and Free-floating forms.*—Under this heading we shall consider those algæ which are found free-floating near the banks of ponds, lakes and tanks or simply entangled in branches of water-plants for they have no special organs in the form of hapterophores or rhizoids for attachment. Zygnemales are very well represented with about nineteen species described by the author alone, and there are surely many more. *Spirogyra* is the commonest form of these, and then come *Ghosella*, *Zygnema*, *Debarya* and *Mougeotia*. *Nodularia fertilissima* sp. nov. may also be seen mixed with *Ghosella indica* (Randh.). *Sphæroplea annulina* may also be commonly seen after February, and in April it becomes fertile in such masses that it

gives a brick-red colouration to many ponds. *Hydrodictyon reticulatum* occurs in most of the big ponds, and small slowly-flowing freshwater streams, from the middle of July to the end of April. In November and December most of the freshwater streams are full of glistening daughter-colonies of this alga. There are very few Myxophyceæ which are found free-floating. *Oscillatoria princeps* may be seen in very muddy and stinking puddles found near most of our village wells or in drains. *Aphanocapsa serpentina* is found in the shape of light blue gelatinous cylindrical masses filling many ponds in Ferozepore district. Then there are certain species of *Anabæna, Rivularia* and *Cylinderospermum*, which may be found free-floating in flocculent masses in some ponds and tanks.

3. *Attached forms.*—Under this group we shall consider the algæ which are found attached to the bottom of ponds, submerged walls of tanks and water-reservoirs, and submerged roots, stems and leaves of water-plants. According to the substratum and object to which they are attached, we subdivide this group into the following subgroups :

1. *Algæ attached to Submerged Soil of Ponds.*—In this subgroup we include that small group of algæ which are found attached to the bottom of ponds where the water is very shallow, seldom being deeper than two feet. So far I have seen only three members of Myxophyceæ which can be dealt with under this subgroup. Of these *Lyngbya perelegans* grows in the form of dirty-brown cylindrical columns attached to the bottom of tanks, and *Anabænothrix cylindrica* in the form of blue-green irregular cylinders attached to the submerged soil of puddles. As there is no specialised organ of attachment, even a slight disturbance in water causes these cylinders to get detached from the bottom, and the alga becomes free-floating. It is only its method of growth which has given the alga an attached habit. The alga firstly grows on the submerged soil, and then the distal part of the colony grows up towards light, and the mucus of the colony assumes a cylindrical shape. The third alga is *Nodularia spumigena* which grows in deep blue coralline masses, mixed with grass, in the shallow water of Budha Nala at Ludhiana.

2. *Algæ attached to the Sides of Water-Reservoirs and Steps of Tanks.*— This group includes many members of Myxophyceæ and some Green Algæ which are found attached to the brick-work of the walls of water-reservoirs or wells, and the steps of tanks. Of these *Schizothrix mexicana* may be seen in deep bluish-green velvet-like bunches in the sides of water-reservoirs, used for watering cattle in villages, adjacent to wells. Another common alga is *Rhizoclonium hieroglyphycum* which is found on brick-work under water taps.

3. *Algæ attached to Twigs and Water-Plants.*—This subgroup is further subdivided into two sections, according to the nature of the substratum.

(a) *Algæ attached to Twigs and Dead Branches of Plants.*—The algæ which are included in this subgroup have developed definite organs of attachment in the form of rhizoids or flattened basal cells. Some of them may be found growing attached to the sides of the submerged steps of tanks, but most of them are found attached to stones or dried sticks and branches of trees. It has been noticed that these forms show a decided preference for non-living substratum and it is very rarely that they may be seen attached to living aquatic plants. These forms are totally submerged for the most part of their existence. *Stigeoclonium*, with its four common species, *S. lubricum, S. subuligerum, S. amœnum* and *S. tenue*, is a typical representative of this group. Next comes *Ulothrix* with four species, *U. zonata, U. tenuissima, U. tennerima* and *U. subtilissima*.

(b) *Algæ attached to Living Plants.*—In this subgroup those algæ have been dealt with which usually grow on living leaves, stems and roots of water-plants or living filaments of big algæ like *Cladophora* and *Sirogonium*. This subgroup may be roughly divided into two sections, the difference mainly being that members of the second section are microscopic in size, and are not obvious to the naked eye, while the members of the first section are big in size and conspicuous.

*Section* 1. *Macroscopic Forms.*—Most of these epiphytes have well-developed basal cells for attachment. *Oedogonium* is the commonest of these with 14 species of which *Oe. cardiacum, Oe. urbicum, Oe. inerme, Oe. Sociale* and *Oe. Hirnii*, are fairly common on leaves of water-plants and in the month of April they produce a multi-coloured harvest of oospores. Other common members of this section are *Schizomeris irregularis, Ulothrix oscillarina, Pithophora Kewensis, Cladophora glomerata, Chætomorpha aerea* and attached species of *Spirogyra*. It may be marked, that most of these algæ, which have organs for attachment, are the same as those found in flowing water, and have developed these organs even in a still water environment.

*Section* 2. *Microscopic Forms.*—These are algæ which are usually microscopic in size, and grow as epiphytes not only on common phanerogamic water-plants, but also on other algæ like *Sirogonium, Cladophora* and *Pithophora*, which do not produce any mucilage and hence become loaded with epiphytes. Abdul Majeed has studied the epiphytic Diatoms of the Panjab and according to him most of the filamentous algæ, and especially those mentioned above, are found loaded with species of *Synedra*,

*Achnanthes hungarica, Cocconeis placentula, Gomphonema · intricatum, G. subapicatum, G. constrictum* and *Epithemia arcus.* Most of these Diatoms have mucilaginous hyaline stalks by means of which they are attached to other algæ and water-plants. Other common epiphytes are *Aphanochæte repens, Coleochæte soluta, C. scutata, Chætosphæridium globosum, Bulbochæte* and species of *Characium.* Myxophyceæ are represented by *Chamæsiphon filamentosa, Anabænothrix epiphytica* and *Cylinderospermum Michailovskænse.*

## *Conclusion.*

Very little work has been done on the ecology of the freshwater algæ of North India, and this is, as far as I know, the first attempt in this field. Under such circumstances, it may be expected that considerable variety of opinion be entertained by various algologists as to the best method of arranging the various forms in Groups, Subgroups, Sections and Sub-Sections. The author realises that more intensive work is required in this field, and his conclusions in some cases may not be all what is desired. However, he hopes that his efforts will stimulate the workers, who have better facilities than he has for this sort of work.

The writer sincerely thanks Doctors S. L. Ghose, H. Chaudhuri and P. L. Anand, of the Panjab University, for their advice and criticism.

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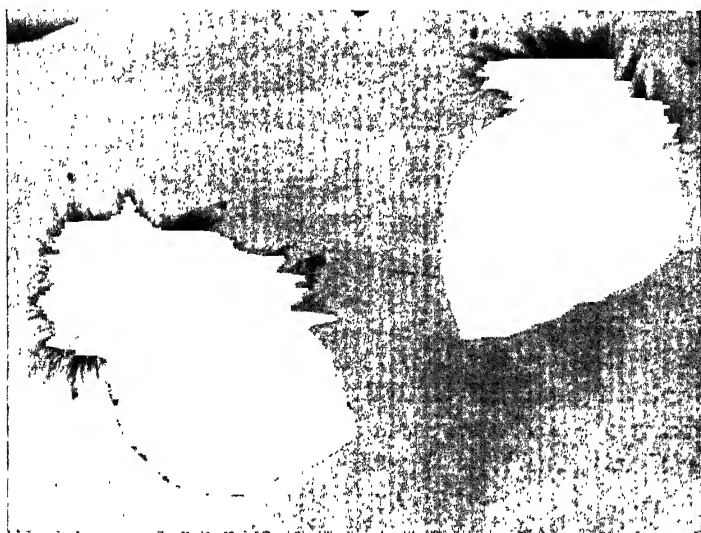
FIG. 1.

*Cladophora glomerata* growing on Gastropods.

# A NEW GENUS OF TREMATODES OF THE SUB-FAMILY TYPHLOCOELINAE FROM THE SHOVELLER DUCK, *SPATULA CLYPEATA*.

BY MAKUND BEHARI LAL.

*(From the Department of Zoology, Lucknow University, Lucknow, India.)*

STOSSICH (1902) created a sub-family Cyclocœlinæ for the reception of four genera *Cyclocœlum* Brandes, *Hæmatotrephus* Stossich, *Ophthalmophagus* Stossich and *Typhlocœlum* Stossich. Kossack (1911) raised it to the status of a family Cyclocœlidæ and included two new genera *Hyptiasmus* and *Spaniometra* in it. He also included the genus *Bothriogaster* under this family. Harrah (1922) while revising the Monostomes of North America divided the family Cyclocœlidæ into three sub-families :

1. Cyclocœlinæ Stossich with the genera *Cyclocœlum*, *Hæmatotrephus* and *Hyptiasmus*.

2. Typhlocœlinæ Harrah with the genera *Typhlocœlum* and *Tracheophilus*.

3. Ophthalmophaginæ Harrah with the genera *Ophthalmophagus*, *Bothriogaster* and *Spaniometra*.

Witenberg (1926) revised the classification of the family Cyclocœlidæ taking the character of the cæcal diverticula as of sub-family status. He fused the sub-families Ophthalmophaginæ and Cyclocœlinæ, leaving only two sub-families Cyclocœlinæ and Typhlocœlinæ under the family. He also created a number of tribes, some new genera and species in which he considered the relative position of gonads, uterine coils, and distribution of the vitellaria as basic characters. Joyeux and Baer (1927), while differing from Witenberg, suggest the fusion of all the forms of Cyclocœlidæ into three genera. They do not consider the cæcal diverticula sufficiently important for the formation of the sub-families, but regard them only of a generic value in the same way as the relative position of the gonads.

The sub-family Typhlocœlinæ Harrah contains two genera, *viz.*, *Typhlocœlum* and *Tracheophilus*. The present communication deals with the description of a new genus under the sub-family.

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I wish to acknowledge my indebtedness to Dr. G. S. Thapar, for his guidance during the course of this work and record my sincere thanks to him.

## Typhlophilus shovellus *N.G.*, *N.Sp.*

Several specimens of this trematode were obtained twice from the small intestine of the shoveller duck, *Spatula clypeata* at Lucknow. This habitat appears to be peculiar as the Cyclocœlidæ chiefly infest the air-passages. The trematode showed very little activity till they had remained in warm normal salt solution for about 10 minutes. They were light grey in colour and ribbon-like.

The length of the specimen is 3·6 mm. and its maximum width which is a little behind the ventral sucker is 1·15 mm. The oral sucker is extremely feeble, in the form of a funnel-shaped depression and measures ·19 mm. × ·195 mm. About the middle of the body is a circular well-developed ventral sucker which has got a muscular wall surrounding a shallow cavity in the centre. It measures ·125 mm. in diameter and is very distinctly seen even in whole mounts.

The mouth leads into a small prepharynx which is slightly curved in the middle and measures ·2 mm. in length. It is followed by a globular pharynx which is thick-walled and measures ·19 mm. in length and ·21 mm. in breadth. The œsophagus is extremely small so that the intestinal cæca seem to arise immediately behind the pharynx. The intestinal cæca present short diverticula on their inner side, about 10 in number, and join posteriorly to form the so-called 'Intestinal Bow'.

The excretory system is not very clearly seen due to the coils of gravid uterus but the excretory bladder is quite distinct. It is crescent-shaped—concave in front and convex behind—and lies in the space between the 'Intestinal Bow' and the posterior end of the animal. It measures ·35 mm. in length and opens out by the dorsally placed excretory pore a little in front of the posterior end of the animal.

The testes, two in number, lie in grape-like bunches, one lying in the 'Intestinal Bow' and the other one in front of it on the left side behind the last cæcal diverticulum. The anterior testis, which is separated from the posterior by the first coil of the uterus, measures ·125 mm. × ·06 mm. The posterior testis measures ·15 mm. × ·07 mm. The vasa deferentia meet anteriorly to form the vesicula seminalis which lies at the base of a flask-shaped cirrus sac; the latter measures ·25 mm., has a bent neck and contains a feeble cirrus. The pars prostatica or the prostate gland-cells could not be distinguished.
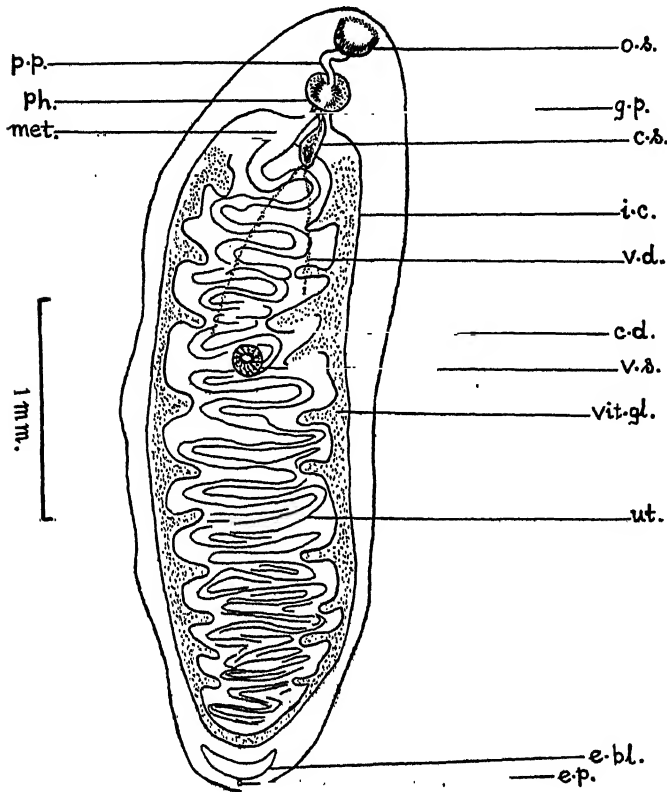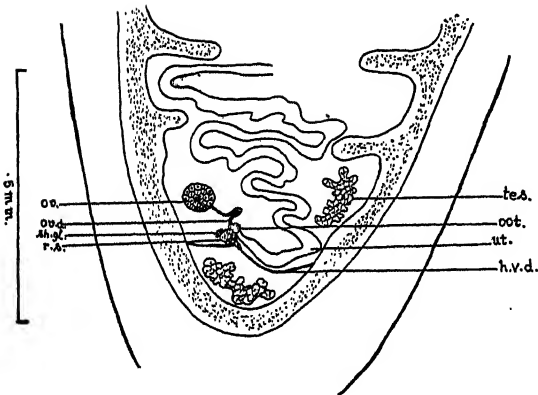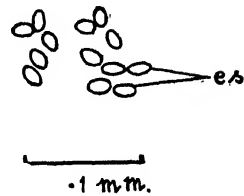
FIG. 1.



FIG. 2.



FIG. 3.

The ovary which lies, at the level of the left testis, on the right side is oval and measures ·055 mm. × ·07 mm. The small narrow oviduct, emerging from the left side of the ovary, opens into a small globular öotype into which

also open the horizontal vitelline ducts. Behind the öotype lies a small oval receptaculum seminis surrounded by a large number of shell-gland cells. The uterus arises from the left side of the öotype and after almost touching the intestinal cæcum on the left side runs forward in thick transverse loops. It is confined between the two intestinal cæca and ends anteriorly in a thick-walled metraterm opening at the genital pore which is situated ventral to the intestinal bifurcation just behind the pharynx. The uterus is full of small eggs measuring ·02 mm. × ·01 mm. They have a thin shell and are not provided with any polar filament.

The vitelline glands are diffuse and run almost ventral to the intestinal cæca and their diverticula. They also meet together posteriorly at the 'Intestinal Bow' so that they form one continuous stream. Anteriorly they extend a little beyond the level of the first cæcal diverticulum.

The characters of the genus *Typhlophilus* may be summed up thus :—

1. Distome, with a flat ribbon-like body, and with an extremely feeble funnel-shaped oral sucker and a small muscular ventral sucker.

2. Curved prepharynx, globular pharynx and extremely small œsophagus.

3. Intestinal cæca, provided with about 10 diverticula on the inner margin, meet in the middle posteriorly to form the Intestinal Bow.

4. Excretory bladder crescent-shaped, excretory pore dorsal and sub-terminal.

5. Testes, two, in grape-like bunches separated from each other by the first coil of the uterus. The anterior testis lies on the left and near intestinal cæcum, the posterior fills the arch near the Intestinal Bow.

6. Ovary oval, on the right side at the level of the left testis. Öotype, shell-gland and a small receptaculum seminis present between the ovary and the posterior testis.

7. Genital pore situated ventral to the intestinal bifurcation, immediately behind the pharynx.

8. Eggs small, thin-shelled, without filaments.

The present genus *Typhlophilus* differs from *Typhlocœlum* in the separation of the testes by the first coil of the uterus and in the position of the ventral sucker. It differs from the other genus *Tracheophilus* in possessing a ventral sucker, and grape-like bunches of lobed testes. From both these genera, *viz.*, *Typhlocœlum* and *Tracheophilus*, it differs, however, in the

situation of the genital pore ventral to the intestinal bifurcation, in having a curved prepharynx, in the crescent-shaped excretory bladder and in possessing a small oval receptaculum seminis behind the öotype. These features appear to be sufficiently important for the creation of a new genus *Typhlophilus* with *Typhlophilus shovellus* as the type species.

*Key to the Genera of the Sub-Family Typhloccælinæ.*

1.   Ventral sucker present, testes lobed . . . . . . . . .        2
    Ventral sucker absent, testes rounded. . . . . . . . .*Tracheophilus.*

2.   Testes confluent or not separated from
        each other by a coil of the uterus. . . . . . . . . . .*Typhloccælum.*
    Testes always separated from each other
        by a coil of the uterus, receptaculum
        seminis present  . . . . . . . . . . . . . . . . . . . . . . . .*Typhlophilus n. g.*

*Remarks on the Classification of the Family Cycloccælidæ.*

Two main classifications of the family Cycolcoelidæ have been recognised so far, one by Witenberg (1926) and the other by Joyeux and Baer (1927). The main difference between the two classifications is as regards the systematic value of the cæcal diverticula. Witenberg regards the presence or absence of the cæcal diverticula as a sub-family character while Joyeux and Baer consider it only of a generic value in the same way as the relative position of the gonads.

Although the various genera of Cycloccælidæ differ from one another in the position of gonads, uterine coils and genital pore, yet all of them can be arranged under two distinct groups on the basis of the cæcal diverticula. These two groups thus formed show remarkable parallel variations in some of the important structures of their respective members. The position of ovary in relation to testes, the relation of uterine coils to the gonads and the position of the genital pore are not constant in any of the two groups but vary with the different genera possessing cæcal diverticula and those others without them. It is, thus, apparent that these two groups based on the cæcal diverticula form the true natural divisions of the family Cyclo-coelidæ. The character of cæcal diverticula, therefore, should form the basis of the two sub-families Cycloccælinæ and Typhloccælinæ and the author is in full agreement with the view of Witenberg.

.   The relative position of the gonads is another character of systematic value. Joyeux and Baer reduce all the genera of the sub-family Cycloccælinæ mentioned by Witenberg to two chief genera—*Cycloccælum* and *Spaniometra*. They include all those forms which have their ovary either pre-testicular or inter-testicular under the genus *Cycloccælum*. The position of the ovary,

B4                                                                    F

in front of the two testes, is quite discriminative and different from that of the ovary in between the two testes. They are two distinct characters and cannot be combined under one genus. The contention of Joyeux and Baer in reducing the genera of Cyclocœlinæ on this basis does not, therefore, appear to be correct.

Besides these differences of opinion with regard to the classification of the family under review, some interesting material for discussion has been afforded by the discovery of a ventral sucker in some members of the family. Cohn (1904) and Fuhrmann (1904) regarded the presence of a ventral sucker as a distinct and important family character. They wanted, therefore, to remove the forms which possess a ventral sucker from the family Cyclocœlidæ. On the other hand, Morishita (1924), Witenberg (1926) and Joyeux and Baer (1927) consider ventral sucker merely as a specific variation. It is advisable under the circumstances, to regard it as a generic character for the present till its presence in the larval stages of these trematodes is indicated.

### EXPLANATION OF FIGURES.

Fig. 1.—*Typhlophilus shovellus* n.g. n.sp., ventral view, showing the disposition of the internal organs.

Fig. 2.—*Typhlophilus shovellus* n.g. n.sp., ventral view, showing the genital glands and the öotype complex.

Fig. 3.—*Typhlophilus shovellus* n.g. n.sp., showing eggs.

### LIST OF ABBREVIATIONS USED IN THE FIGURES.

| | | | | | |
|---|---|---|---|---|---|
| c.d. | .. | .. Cæcal diverticulum. | ov. | .. | .. Ovary. |
| c.s. | .. | .. Cirrus sac. | ov.d. | .. | .. Oviduct. |
| e.bl. | .. | .. Excretory bladder. | ph. | .. | .. Pharynx. |
| es. | .. | .. Eggs. | p.p. | .. | .. Prepharynx. |
| e.p. | .. | .. Excretory pore. | r.s. | .. | .. Receptaculum seminis. |
| g.p. | .. | .. Genital pore. | sh.gl. | .. | .. Shell gland. |
| h.v.d. | .. | .. Horizontal vitelline duct. | tes. | .. | .. Testis. |
| i.c. | .. | .. Intestinal cæcum. | ut. | .. | .. Uterus. |
| met. | .. | .. Metraterm. | v.d. | .. | .. Vas deferens. |
| oot. | .. | .. Öotype. | v.s. | .. | .. Ventral sucker. |
| o.s. | .. | .. Oral sucker. | vit.gl. | .. | .. Vitelline glands. |

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# ANATOMY OF THE VEGETATIVE PARTS OF TWO TIBETAN *CARYOPHYLLACEAE—ARENARIA MUSCIFORMIS* WALL. AND *THYLACOSPERMUM RUPIFRAGUM* SCHRENK.[1]

BY PRAKASH CHANDRA JOSHI, M.Sc.

(*From the Department of Botany, University of the Panjab, Lahore.*)

## *Introduction.*

*Arenaria musciformis* Wall. and *Thylacospermum rupifragum* Schrenk. are two perennial Caryophyllaceous plants of the elevated trans-Himalayan region. The latter is restricted only to Western Tibet, while the former is also found in Central Tibet (Hooker, 1875). They reach as high an altitude as 20,000 ft. or more above the sea-level (Kashyap, 1932). The climate of these parts is well known and is that of an alpine desert, characterised by rarefaction of its atmosphere, extreme temperatures, strong insolation, low precipitation, strong desiccating winds and great dryness as a whole. The growing season is restricted to only a few summer months. From the late Prof. Kashyap's personal observations it is known that the plants form cushions scattered at a distance from each other. The cushions of *Arenaria* (Pl. III, Fig. 1) are comparatively small and less compact and those of *Thylacospermum* (Pl. IV, Fig. 1) are fairly large and extremely compact. The stem in both the plants, although very short, is woody, much branched and densely leafy. The leaves are small and narrow with a somewhat sheathing base. The roots of the plants are long, branched and woody.

As these plants are quite peculiar in their habit and habitat, it was thought that a detailed investigation of them might yield some interesting results regarding their internal anatomy and development as influenced by the extraordinary environmental conditions. The present paper deals with the anatomy of the vegetative parts only, another paper is to describe some stages of the development of the flowers of the two plants.

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[1] A preliminary note describing the stem and root anatomy of *Thylacospermum rupifragum* appeared in *Curr. Sci.,* 1935, **3**, 300–301.

*Materials and Methods.*

The material of both the plants was collected from Kiangtso plain, Rupshu[2] (altitude 15,000 ft.) in July 1933 by Mr. P. N. Mehra, who accompanied the late Prof. Kashyap on a botanical excursion in that part. It was all fixed in formalin-acetic alcohol. The stem anatomy of *Arenaria,* however, was mostly studied from dry herbarium material. Besides cutting hand sections, the material was imbedded in paraffin and serial sections were cut 10–15 $\mu$ in thickness.

*Arenaria musciformis* Wall.

*Structure of the leaf.*—The walls of the epidermal cells on both the upper and the lower surfaces of the leaf are straight and not undulate as is usual in the dicotyledons. Superficial stomata are present on both the surfaces, but they are more abundant over the distal part of the lower one. Unlike most other *Caryophyllaceæ* (Solereder, 1908), they are not accompanied by any subsidiary cells (Text-Fig. 1). The outer walls of the epidermal cells are cuticularised all over the leaf, but the thickening is more marked near
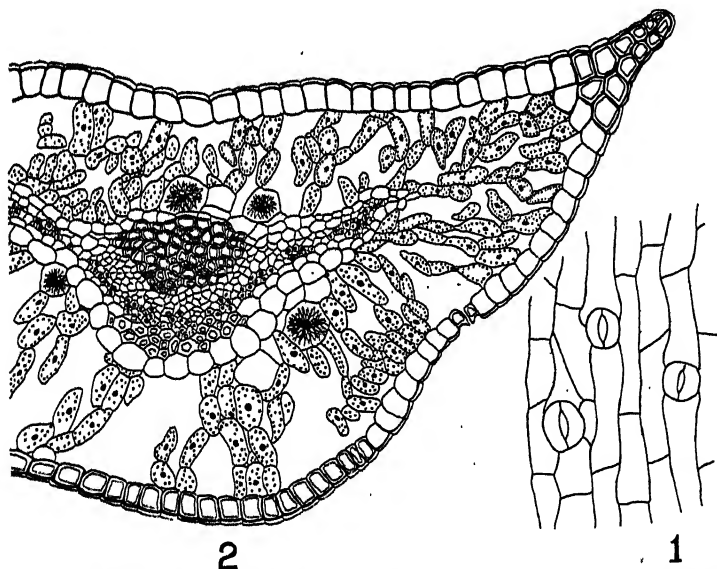


TEXT-FIGS. 1–2.—*Arenaria musciformis* Wall. Fig. 1.—Epidermis of leaf, showing absence of subsidiary cells in stomata. × 700. Fig. 2.—Part of t.s. leaf. × 700.

the margins and the middle of the lower surface. The vascular tissue of the leaf consists of a single large bundle (Text-Fig. 2) and a cap of

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[2] Politically, the region is not included in Tibet proper, but geographically it is a part of Tibet, as it possesses exactly the same climate and topography.

sclerenchymatous tissue is present on the outside of the phloem. Clustered crystals of calcium oxalate are quite common in some of the parenchymatous cells, especially in the neighbourhood of the vascular bundle. The mesophyll of the leaf shows no differentiation of the palisade tissue ; it consists entirely of spongy tissue with abundant inter-cellular spaces.

In the basal part of the leaf the mesophyll consists of ordinary parenchyma.

*Structure of the stem.*—The primary structure of the stem of *Arenaria* is that of an ordinary dicotyledonous plant. Text-Fig. 3 is an outline sketch of a transverse section of the young stem and Text-Fig. 4 shows detailed structure of a part of it. It is seen that inside the epidermis there is a cortex of 5–6 layers of parenchymatous cells. There is no distinct endodermis. The cells of the innermost cortical layer are rather irregularly arranged. The pericycle is formed of 4–6 layers of cells, its cells opposite the bundles being smaller. The number of vascular bundles in the stele varies from 5–6 and the size of the different bundles in a cross-section is also variable. Each bundle consists of a fairly large amount of small-celled phloem, nearly three layers of intrafascicular cambium and comparatively meagre xylem. Clustered crystals of calcium oxalate are abundant in the cells of the cortex and the pith.

The secondary growth commences at a very early period. The cambium of the bundles develops xylem and phloem in the normal manner. Interfascicular cambium is never formed so that even in sections at the base of the stem individual bundles are seen separated from each other by medullary rays of varying width (Text-Fig. 5). A thick cork is formed in the outer part of the stem by the phellogen.

Secondary xylem is peculiar in that it consists of two kinds of vessels, one with narrow lumina and the other with wider lumina with spiral or reticulate thickenings of the walls, scattered in an unlignified ground tissue. The pitted vessels are altogether absent.

The secondary growth does not take place equally all round the stem, it being more pronounced on one of the sides than the other. Moreover, in one bundle the activity of the cambium may not be uniform in its whole length ; this may give rise to a furrowed appearance (Text-Fig. 5). It is to be seen later that such a behaviour of the cambium is met with in a more pronounced form in the root.

In older parts of the stem the depositions of calcium oxalate are very numerous and large. They break the cells containing them and thus lead to the formation of intercellular cavities.
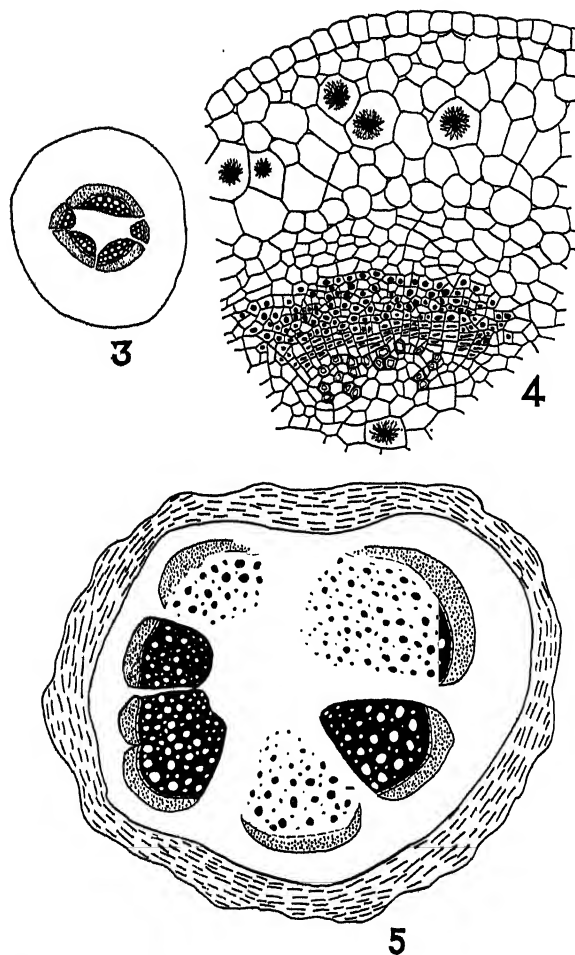
TEXT-FIGS. 3–5.—*Arenaria musciformis* Wall. Fig. 3.—T.s. young stem.  $\times$  100. Fig. 4.—Part of the above in detail.  $\times$  700. Fig. 5.—T.s. old stem, showing the presence of a thick cork on the outside; thickening in the stele is more pronounced on one side than the other and in a bundle on left hand side the activity of its own cambium is unequal.  $\times$  60.

*Structure of the root.*—The primary structure of the root could not be studied as proper material was not available and moreover in rootlets, as small as $\frac{1}{2}$ mm. in diameter, so much secondary growth had taken place as to obliterate the primary structure completely. A root as thick as 3 or 4 mm., however, in its essential features is quite normal, as in a transverse section it consits of a perfectly circular solid cylinder of wood in the centre and a uniform ring of bast on its outside with an intervening complete cambial layer. Cork is also normally formed outside the cortex.

The composition of the secondary vascular tissues is similar to that of the stem (Pl. III, Fig. 3). The medullary rays are completely absent as in other members of this family (Solereder, 1908). With further thickening in the root the activity of the cambium of the central cylinder ceases to be uniform; it becomes restricted and later altogether lost at several places so that the increase in the amount of xylem is not equal throughout the circumference. The woody cylinder thus becomes furrowed at several places, the furrows increase in depth as the secondary growth advances. This internal irregularity in the form of the xylem mass does not, in any way, affect the external form of the root so that a transverse section of a fairly thick root is quite circular on its outside while the central wood is lobed (Pl. III, Fig. 2). Numerous clustered crystals of calcium oxalate are deposited in the old cells of the phloem and the xylem parenchyma. These increase in size in the same manner as in the stem and destroy many cells.

### *Thylacospermum rupifragum* Schrenk.

*Structure of the leaf.*—The structure of the leaf of *Thylacospermum* is mostly like that of *Arenaria*. Stomata occur almost equally on both the surfaces and like those of *Arenaria* they are superficial and have no subsidiary cells (Text-Fig. 6). The mesophyll consists only of spongy tissue with numerous inter-cellular spaces (Text-Fig. 7). The vascular tissue is not accompanied by sclerenchyma.
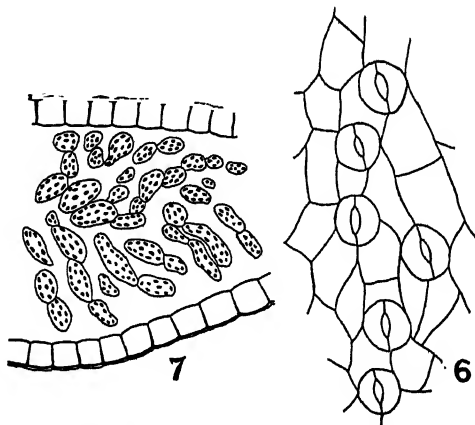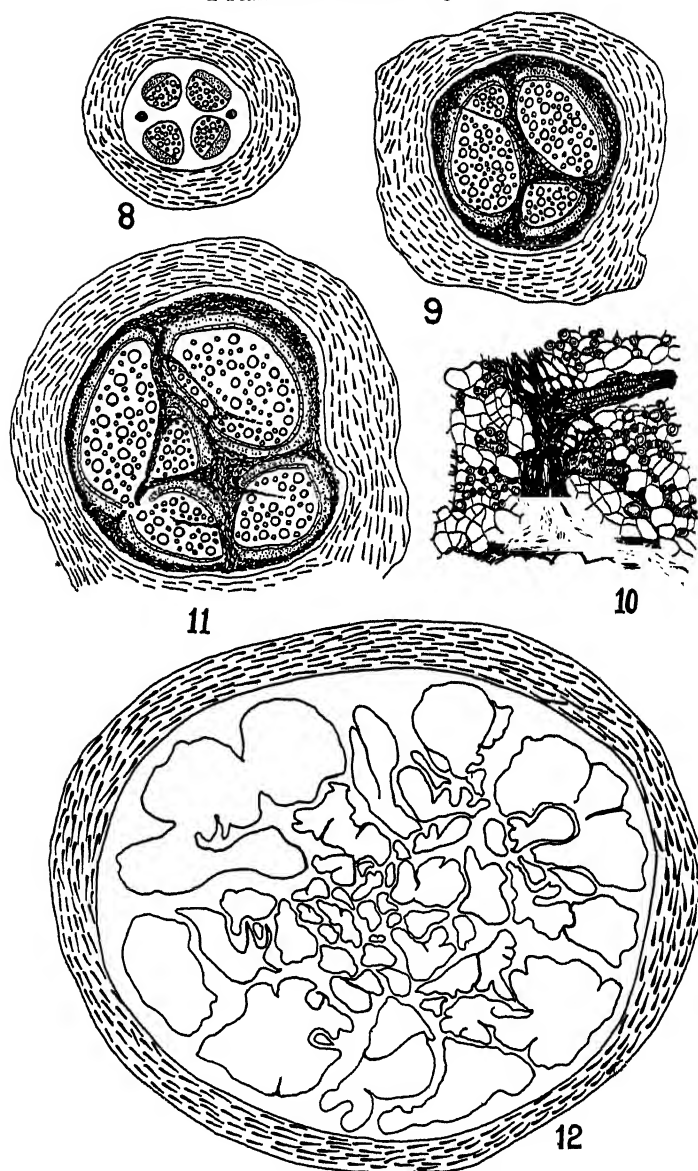


TEXT-FIGS. 6–7.—*Thylacospermum rupifragum* Schrenk. Fig. 6.—Epidermis of the leaf. $\times$ 700. Fig. 7.—Part of t.s. leaf, showing presence of only a spongy mesophyll. $\times$ 700.

*Structure of the stem.*—The primary structure and early secondary growth in the stem of *Thylacospermum* resembles that of *Arenaria* in the arrangement of the main tissues. The secondary growth, however, begins much earlier. Text-Fig. 8 is an outline sketch of a young stem about 1 mm. in diameter,

This shows on the outside a thick protective covering of cork, the phellogen and 3 to 4 layers of cortical parenchyma. The stele consists of four large bundles in a ring. Moreover, in the section there are also two small outgoing leaf-traces. The cells of the pith, medullary rays and the cortical tissue are large, thin-walled and soft. During secondary thickening the primary cambium of the bundles never forms a complete ring. Only occasionally two adjacent bundles may unite with each other by the development of an inter-fascicular cambium, while other bundles of the ring remain quite separate. Secondary xylem, as in *Arenaria*, consists of narrow and wider spiral or reticulate vessels indiscriminately scattered in large amount of ground tissue formed of thin-walled and somewhat longitudinally elongated parencyhma. The phloem appears to be destitute of sieve tubes and companion cells, and seems to be composed uniformly of prosenchymatous cells. The cells are at first narrow and thin-walled but as they grow old they become comparatively large and thick-walled. The cambium is somewhat peculiar in that in a transverse section it does not consist of the usual tangentially elongated cells, but rather of small dividing cells nearly of equal dimensions. Secondary thickening in the bundles consists in the formation of new vascular elements and appears to take place quite rapidly. Externally the thick and comparatively stiff layer of cork resists such an extension of the stele. This results in pressing of the soft tissues of the pith, medullary rays and the inner cortex, and their ultimate distortion and rupture. In figures of the plant the zone of disintegration is represented by thick black dotting.

Departure from the normal stem structure occurs during the latter part of the secondary growth due to an unusual activity of the xylem parenchyma. While normal increase in the vascular cylinder is going on through the activity of the primary cambium, some of the cells of the old wood parenchyma on the side of the pith enlarge, assume meristematic activity and so constitute small strips of secondary cambium on the inside of the normal vascular ring (Text-Figs. 9 and 10). The required space for this new internal activity in the stele is supplied partly by distintegration of the surrounding xylem parenchyma and its vessels and partly by the disintegration of the medullary tissue already mentioned. The strips of the secondary cambium in the different bundles extend laterally and may meet one another or the primary cambium of the same bundle, but such a union is only temporary as soon afterwards a rupture of the zone occurs. Roughly speaking, the secondary cambial strips develop xylem on the side facing the xylem formed from the primary cambium and phloem on the side removed from it. Histologically the vascular tissues, produced by the two types of cambium, are similar.
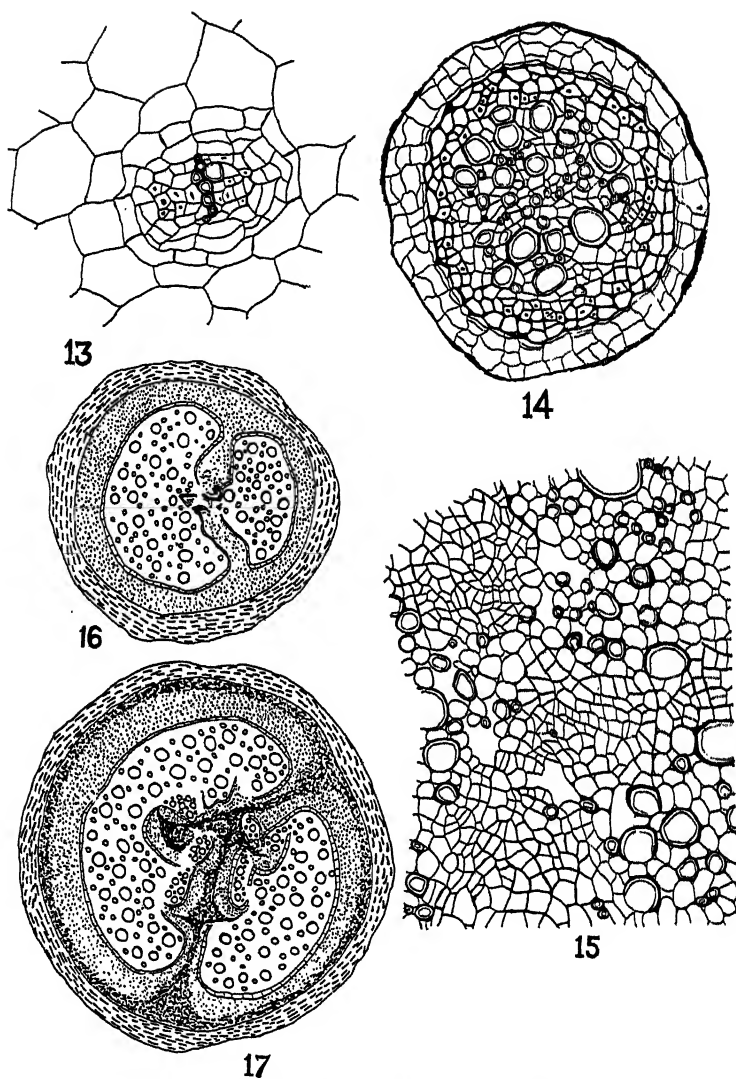
TEXT-FIGS. 8–12.—*Thylacospermum rupifragum* Schrenk. Fig. 8.—T.s. young stem, showing
the presence of a thick cork on the outside; the stele consists of 4 vascular bundles
besides two small outgoing leaf traces.  $\times$ 35. Fig. 9.—T.s. of an older stem,
showing disintegration of the inner cortical and medullary tissues and origin of
secondary cambium in the wood parenchyma on the side of the pith in the form
of small strips.  $\times$ 35. Fig. 10.—Part of the above diagram in detail, showing
meristematic activity in some cells of the wood parenchyma.  $\times$ 700. Fig. 11.—
T.s. of a still older stem, showing early fission of the vascular tissue due to the
activity of the secondary cambium.  $\times$ 35. Fig. 12.—T.s. of a very old stem,
showing the splitting of the stele into numerous vascular strands (xylem and phloem
is not shown distinct from each other).  $\times$ 10,

Sooner or later vascular tissue, resulting from the activity of the different secondary cambial strips, becomes distinct from the original vascular tissue by crushing the surrounding cells. Thus internal vascular strands carrying on their own independent growth are differentiated (Text-Fig. 11). With the continued growth of the stem and without the cessation of the activity of the normal cambium, more and more strips of secondary cambium appear in the xylem of the original bundles. They also produce similar vascular strands of varying form and dimensions. Activity of the normal cambium does not cease with the apppearance of new bundles, but its uniformity suffers. The production of wood on its inside is most unequal in the different parts, so that the bundles on the outside become deeply divided or lobed and the cambium in the furrows ceases to be active or becomes obscure. With further growth, more strips, arcs or rings of cambium appear in the xylem parenchyma of the different bundles which results in the formation of many additional strands, each developing wood and bast by means of its own cambium (Pl. IV, Fig. 2). As a consequence of this enormous activity in the xylem parenchyma the original tissues are displaced and crushed to such an extent that finally the whole shoot inside the cork consists of numerous strands of wood, cambium and bast, irregularly arranged and of very varied form (Text-Fig. 12). In longitudinal sections these bundles are frequently seen to anastomose with one another.

*Structure of the root.*—The primary structure of the root has been studied from small rootlets coming out from the main roots. The epidermis and most of the cortical cells were not found in tact in all these rootlets. Text-Fig. 13 represents a transverse section of the youngest rootlet seen by the writer. There is seen a distinct endodermis surrounding the stele which, in its centre, has a somewhat irrelguar diarch xylem plate alternating with two phloem groups. Most of the cells of the outermost layer of the pericycle have divided tangentially in order to produce a phellogen. The primary structure of the root is only short-lived.

The first or the primary cambium in its origin and early behaviour appears to be perfectly normal. On the outside it develops phloem all round on the inside secondary xylem throughout its legnth ; thus no medullary rays are formed. The primary xylem plate is altogether obliterated and the primary elements are not distinguishable in a root as small as 1 mm. in diameter (Text-Fig. 14). The cell structure of the secondary vascular tissues is similar to that of the stem. The phellogen forms on the outside of the root a thick layer of cork as in the stem, but on inside it produces little phelloderm.

TEXT-FIGS. 13–17.—*Thylacospermum rupifragum* Schrenk. Fig. 13.—T.s. rootlet with incomplete cortex, showing diarch primary structure. × 700. Fig. 14.—T.s. root, showing early secondary growth in an almost normal manner. × 700. Fig. 15.—Portion of t.s. of quite a young root, showing meristematic activity of some cells of the wood parenchyma in the centre to form secondary cambium. Figs. 16–17.—T. s. of older roots, showing development of secondary cambium and early fission of the original vascular cylinder (actually strips of secondary cambium could not be seen so continuous as shown). × 35.

While the root is still quite young, the activity of the cambial ring is generally arrested at one, two or three points on its circumstance and soon afterwards, the cambium at these places becomes obscure. As a result

of this, the cambial ring is split into a number of arcs which develop xylem and phloem in the normal manner (Pl. V, Fig. 1).   Serial transverse sections show that the position of the points at which the cambial activity is arrested and their number varies in the different parts of the roots.   Occasionally the cambial ring is seen to be quite perfect even in the higher regions. The activity of the cambial arcs is comparatively slow at the ends.   The arcs, therefore, become curved inwards at the ends. Almost simultaneously with the breaking of the primary cambial ring, strips of secondary cambium, similar to those of the stem, develop in the wood by the divisions of its parenchymatous cells (Text-Fig. 15).   Generally, they are first to appear in the centre of the stele and in the region of the radii joining it with the points where the primary cambium has stopped its activity (Text-Fig. 16). Perhaps the latter is a result of this anomalous secondary activity.   The strips extend laterally and generally the outer become continuous with the inward projecting ends of the arcs of the primary cambium.   The secondary cambium, more or less as a rule, produces xylem as in the stem facing the xylem formed from the primary cambium and phloem on the reverse side (Text-Fig. 17).   With further growth and without the activity of the primary cambium ceasing, the original wood of the root is split up successively into a number of vascular strands, each with its own normal cambium producing wood and bast as in the stem (Pl. V, Figs. 2–4).   Roughly speaking, the splitting proceeds in a centrifugal succession on from the centre to the periphery, but the 3 or 4 arcs of the vascular tissue formed from the primary cambium are not much broken in their outer part and remain as such even in the oldest roots, when the more internal xylem has become extremely divided and split up into numerous strands.   The longitudinal course of the strands is highly irregular; they are frequently connected laterally with one another and with the peripheral normal xylem by anastomoses as in the case of the stem.

## Discussion.

The fluted wood cylinder of the roots of *Arenaria* does not appear to be a very important feature, although the cause of the arrested development of the cambium is not known.   Cases showing unequal growth of wood in the stem and root are not very uncommon among the dicotyledons, but they are mostly confined to the stems of lianes, where this phenomenon sometimes appears in striking forms.   It may, however, be mentioned that Bloch (1911) found a considerable amount of asymmetry in the woody cylinder of the underground parts of several alpine plants.   The lobed xylem mass in the roots of *Arenaria* is another instance of a similar kind.   According to Bloch these phenomena can be explained only after thorough experimental studies.

The order Centrospermales to which the family *Caryophyllaceæ* belongs is well known for anomalies of root and stem structure, but these consist mostly in the presence of medullary bundles in the stem or succession of secondary cambial rings outside the normal vascular cylinder in both the root and stem. Anomalies of curious and complicated vascular structure similar to that found in *Thylacospermum* are characteristic of stems of some tropical lianes belonging mostly to the families *Combretaceæ*, *Malpighiaceæ* and *Bauhineæ* (De Bary, 1884). This type of structure is generally considered to be correlated with the climbing habit, but here it is found in just a reverse type of plant—a species with a very stunted stem. Besides lianes to some extent a parallel condition is offered in some fleshy roots (De Bary, 1884). Recently Joshi (1935) has found a somewhat similar anomaly (although it differs in details of development) in the root of another Tibetan plant, *Stellera chamæjasme*, the stem possessing a different type of anomalous structure. It is seen that all these roots store large amount of food substances and Haberlandt (1914) thinks it quite possible that this type of anomalies are related to this feature as these serve to ensure the production of the requisite amount of storage-tissue and thorough inter-penetration of storing and conducting tissues, an arrangement which renders the deposition and renewal of reserve-materials easier and more effective. In both *Thylacospermum* and *Arenaria*, however, no food substances have been seen deposited in any part of the root or stem and there is no special tissue met with suggestive of a storage region. This is evidently due to the fact that in most other plants the aerial parts die during the unfavourable season while the underground parts survive and perennate. At the recommencement of the growing season aerial parts are again produced at the expense of the reserved food storage in the underground parts. In *Thylacospermum* and *Arenaria* the plant as a whole persists during the unfavourable winter months while its growth activities stop altogether and restart only in the beginning of the summer utilising whatever a little food is stored in all the tissues in general. The survival of the aerial parts of the plant in winter is generally believed to be due to the cushion habit, which is in main an adaptation against the intensely dry and cold winds.

Lashevsky (1926) has noted in *Daphne julia*, a member of the same family *Thymelæaceæ* as *Stellera*, that a continued growth of the parenchyma of the pith, wood and wood-rays results in the splitting of the stele into fan-shaped strands arranged in resettes. He believes that the ancestors of the plant were some lianes and the present condition of the structure is an instance of retention of an ancestral condition underground for a very long period. It seems, however, impossible to advance a similar view for *Thylacospermum*,

as the anomaly is not confined to the underground parts but extends to the whole axis and its branches. Moreover, in such a large family as the *Caryo-phyllaceæ* there is not a single climbing plant; the genera closely allied to *Thylacospermum* are herbs or small shrubs.

The writer thinks that the anomalous secondary thickening in *Thylaco-spermum* is of a different origin, independent of any ancestral liane condi-tion and the causes of its origin appear to be of mechanical nature, rather than of any special physiological significance. The extremely compact cushion habit of the plant, which consists in the crowding of numerous branches and leaves in a very short space, is sure to cause a similar crowding of the branch and leaf gaps in the vascular cylinder of the stem. This will allow the extension of the cambium to the inside of the bundles of the normal ring, leading ultimately to the type of structure seen in the stem of *Thylaco-spermum*. From the stem the anomaly will gradually extend to the root, as the vascular system (both primary and secondary) is continuous in the region of the hypocotyl and one always influences the other. The possible advantage of the liane type of structure in *Thylacospermum* is quite clear when one finds that the plant has to face the severity of furious winds of the high plateau and the vascular tissue in the form of a tangle of interwoven strands like that of a rope is sure to render it more pliable and better adapted to resist such forces. It may be mentioned here that a similar function is attributed by Walton (quoted in Seward, 1931) to liane-type of structure in an extinct gymnospermous fossil stem, *Rhexoxylon*, which to all probability was not a liane. Secondary thickening in *Thylacospermum*, therefore, gives a further support to this view that the so-called liane-type of structure in the stem need not necessarily be associated with the climbing habit.

### *Summary.*

The leaves of *Arenaria musciformis* and *Thylacospermum rupifragum* show superficial stomata, abundance of intercellular spaces in the mesophyll which consists of entirely spongy tissue.

The primary structure and early secondary growth in the stem and root of *Arenaria* are more or less normal, but it is found that during later stages of development the activity of the cambium suffers at some points of its extension and this gives rise to furrowing in the wood especially in the root.

The young stems and roots of *Thylacospermum* possess the normal dicoty-ledonous structure, but later the cells of wood parenchyma become highly meristematic and ultimately split the stele into numerous irregular vascular strands in a manner similar to that found in some tropical lianes. This

type of anomalous secondary thickening is new for the family *Caryophyllaceæ* and also for the order Centrospermales itself. It is suggested that in *Thylaco-spermum* it originated independently of any ancestral climbing habit. The cause of its origin is most probably of a mechanical nature.

The writer is highly indebted to the late Prof. S. R. Kashyap, under whom he had the opportunity to work, for guidance and encouragement during the course of this investigation ; the accompanying two photographs of the plants were kindly supplied by him. The writer also wishes to express his grateful thanks to Prof. B. Sahni, of Lucknow University, for several valuable suggestions and criticisms, to Mr. A. C. Joshi, of Benares University, for a revision of the typescript and the benefit of discussing several points with him and to Mr. P. N. Mehra for the material supplied and other help rendered in several ways.

*Note on illustrations.*—Magnifications given are only approximate. In all outline diagrams the cork is represented by short tangential lines, phloem by small dots, cambium by a single layer of cells, xylem parenchyma in case of *Arenaria* by solid black and xylem vessels by spaces in the black, but in case of *Thylacospermum* xylem parenchyma is left entirely white like the rest of medullary and cortical parenchyma, xylem vessels are represented by small circles and the distintegrated tissue by thick black dotting.

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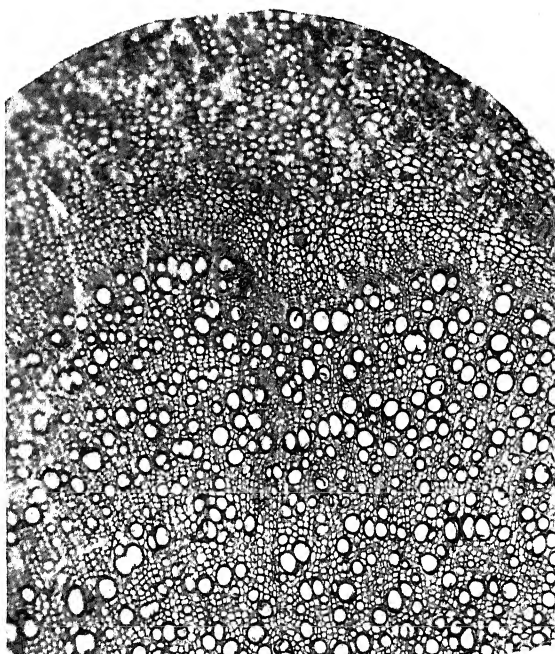
FIG. 1.



FIG. 2.
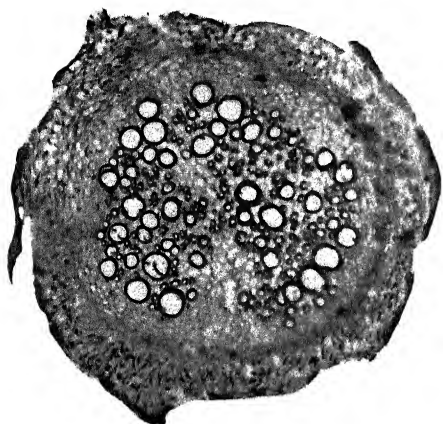


FIG. 3.

FIG. 1.



FIG. 2.

FIG. 1.

FIG. 2.

FIG. 3.

FIG. 4.

## EXPLANATION OF PLATES.

### PLATE III. (*Arenaria musciformis* Wall.)

FIG. 1.—Photograph of a single plant, showing its habit.

FIG. 2.—Microphotograph of a part of t.s. of an old root, showing furrowing of the wood due to unequal activity of the cambial ring and breaking up of the old tissues. $\times$ 13.

FIG. 3.—Microphotograph of a part of t.s. of an old root, showing the scattered arrangement of smaller and larger xylem vessels in an unlignified tissue. $\times$ 60.

### PLATE IV. (*Thylacospermum rupifragum* Schrenk.)

FIG. 1.—Photograph of a single plant, showing an extremely compact cushion habit.

FIG. 2.—Microphotograph of t.s. of a fairly old stem, showing fission of the vascular tissue into several irregular strands. $\times$ 11.

### PLATE V. (*Thylacospermum rupifragum* Schrenk.)

FIG. 1.—Microphotograph of t.s. of quite a young root, showing unequal activity of the normal cambium. $\times$ 80.

FIGS. 2-4.—Microphotographs, illustrating the process of successive fission of the vascular tissue into numerous strands. $\times$ 30; $\times$ 15; $\times$ 10.

B4A                                                                                            F

Coloured Plate No. XXVI (Leaf-Roll and Red Leaf-Blight on Cambodia) refers to the article on "Studies in Disease Resistance—II. Leaf-Roll and Red Leaf of American Cottons" by Messrs. I. Madhusudan Rao and Yeshwant D. Wad appearing in Vol. III, No. 6.
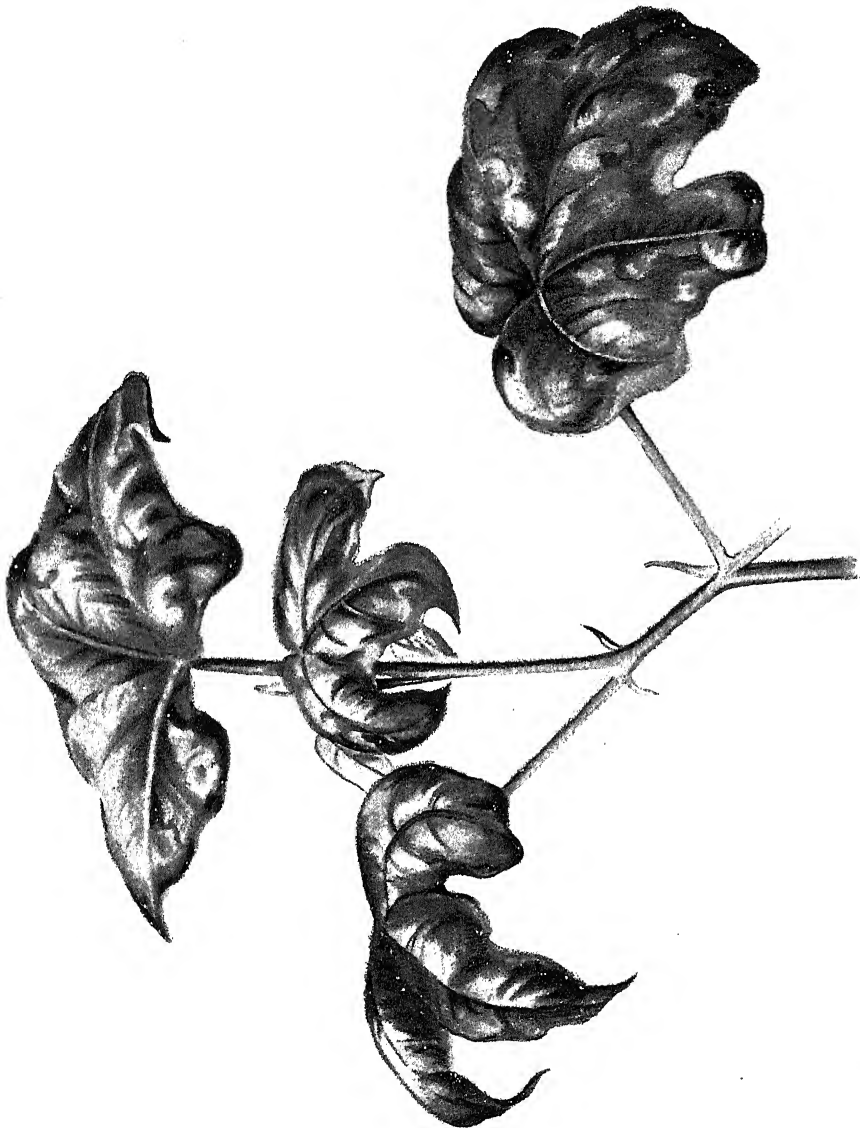
LEAF ROLL AND RED LEAF-BLIGHT ON CAMBODIA.

# STUDIES ON THE MECHANISM OF BIOLOGICAL NITROGEN FIXATION.

Part III. Economy of Carbon during Fixation of Nitrogen by
*Azotobacter chroococcum* Beij.

BY T. R. BHASKARAN, B.SC.

*(From the Department of Biochemistry, Indian Institute of Science, Bangalore.)*

IT has been shown in a previous communication (Bhaskaran and Subrahmanyan, 1935) that during decomposition of glucose by the mixed flora of the soil, the immediate products of decomposition (chiefly the organic acids) are largely utilised for fixation of atmospheric nitrogen. The studies on the carbon transformations during fixation of nitrogen by Azotobacter, particularly by Stoklasa (1908), would suggest that organisms belonging to that genus derive their organic nutrition chiefly from carbohydrates. Working with *Azotobacter chroococcum*, Ranganathan and Norris (1927) observed that the decomposition of sugar was comparatively slow, that the fixation of nitrogen was complete before the entire quantity of sugar was used up. Regarding this observation it is difficult to determine whether it was due to the slow action of Azotobacter or to the smallness of the inoculum. Moreover, as the sugar was present all through in the medium, it is not possible to ascertain whether any of the products of fermentation was used up in the fixation of nitrogen.

Although the general nature of the relation between degradation of carbohydrates and fixation of nitrogen by Azotobacter has received considerable attention (Bonazzi, 1921), further information is nevertheless needed regarding certain important aspects of the problem. Thus, it is not definitely known in what form the degraded organic matter directly helps fixation; what portion of it is taken up by the organisms and how far the growth of the organisms related to fixation. With a view to throwing some light on these and related problems, the present study was undertaken.

## Experimental.

*Isolation of the organism.*—One gram of the local red loam soil was added to 100 c.c. of sterile Ashby's mannite medium and the mixture incubated at 30° C. In two days there was heavy growth in the flask with vigorous frothing and formation of scum at the surface of the liquid. At this

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stage, a loopful was taken from the surface and inoculated into another flask containing the same medium. This operation of sub-culturing was repeated till a microscopic examination showed that many of the contaminating organisms were eliminated. The culture was then plated out on the mannite-agar medium. Such selective sub-cultures yielded finally a pure strain of Azotobacter. The species thus isolated was identified to be *Azotobacter chroococcum* Beij., and this culture was used throughout these studies.

*Technique.*—The general experimental procedure adopted was similar to the one described in the mixed flora studies (Bhaskaran and Subrahmanyan, *loc. cit.*). Instead of using parallel independent samples for the estimation of carbonate, organic carbon and total nitrogen, these were estimated on the same samples by the simplified procedure (Bhaskaran, *et al*, 1936). A slightly modified form of the carbon-nitrogen apparatus has been used.

Here the culture flask itself has been made use of for the digestion—the heating being controlled by a micro-burner. This obviates the need for transferring of the culture, its dilution and the consequent inconvenience in the application of the method for estimation of C and N on the same sample.

A number of carbon-nitrogen estimations were made on a variety of substances using this apparatus. Some of the results thus obtained are given in Table I and would show that the method is capable of giving highly accurate estimates. It is also very rapid.

TABLE I.

| Material | Percentages | | | |
|---|---|---|---|---|
| | Total Carbon | | Total Nitrogen | |
| | Expected* | Found | Expected† | Found |
| Glucose | 39·8 | 39·4 | Nil | Nil |
| Acetanilide | 71·12 | 70·4 | 10·4 | 10·2 |
| Yeast | 34·88 | 34·0 | 5·62 | 5·66 |
| | | 34·6 | | 5·68 |
| Azotobacter (Bac. cells and slime dried) | 43·5 | 43·0 | 3·50 | 3·40 |
| | | 42·8 | | 3·45 |

\* Subrahmanyan, Narayanayya and Bhagvat, *J. Ind. Inst. Sci.*, 1934, **17A**, 197.

† Harihara Iyer, Rajagopalan and Subrahmanyan, *Proc. Ind. Acad. Sci.*, 1936, **3B**, 35.

In order to see whether the volatile fatty acids that are likely to be formed in the medium are included in the estimates of carbon, a few trials were carried out and the results are given in Tables II and III.

TABLE II.

| Expt. No. | Organic carbon (in mg.) in Acetic acid solution | |
|---|---|---|
| | Expected | Found |
| 1 | 21·0 | 20·6 |
| 2 | 42·0 | 40·8 |
| 3 | 63·0 | 63·2 |
| 4 | 84·0 | 83·4 |

TABLE III.

| Material | Organic carbon (in mg.) | |
|---|---|---|
| | Expected | Found |
| Propionic acid | 84·0 | 82·9 |
| Butyric acid | 72·9 | 71·4 |
| Lactic acid | 96·0 | 96·8 |
| Mixture of the above acids | 88·0 | 87·0 |

The results thus show that the air condenser efficiently keeps back all the volatile acids (upto 100 mg. carbon·equivalent of acids) and that fairly accurate estimates of the carbon of the volatile acids can be obtained by the modified apparatus. The apparatus can be conveniently used for a variety of studies on bacterial metabolism.

In addition to the carbon and nitrogen changes, the growth of the organism was also followed. At stated intervals the samples were plated out, the entire contents of one flask being used for each set of dilutions. Ashby's dextrose agar was used as the count medium, the platings being carried out at two convenient dilutions.

It was expected that the dry matter of bacterial cells and slime produced with the progress of the decomposition would furnish an index of the growth capacity of the organism as well as its ability to fix nitrogen.    Since the bacterial mass contained large quantities of water, it was found necessary to dehydrate it.    The investigation of Omeliansky and Seiber (1913) had already shown that desiccation *in vacuo* was not satisfactory.    The following procedure was therefore adopted.    The suspension containing the bacteria with slime was repeatedly shaken up with anhydrous acetone, thorough mixing being ensured by macerating in a mortar.    (The acetone was changed at frequent intervals.)    This treatment led to the ready flocculation and separation of the cells and slime from the liquid, which otherwise would have rendered the subsequent filtration difficult.    The suspension was then filtered through a weighed Jena glass filter (No. 5) and the residue of bacterial cells and slime dried in a steam oven to constant weight.    The method adopted for the estimation of glucose was that described by Bhaskaran, *et al* (1934).

The medium used in these studies had the following composition :

Glucose (A. R.), 10·0 gm. ; Dipotassium phosphate ($K_2HPO_4$), 0·2 gm. ; Magnesium sulphate ($MgSO_4$ $7H_2O$), 0·2 gm.; Sodium chloride (NaCl), 0·2 gm. ; Calcium sulphate, 0·1 gm. ; Manganese sulphate ($MnSO_4$ $4H_2O$), traces ; Ferric chloride, traces ; and Distilled water, 1000 c.c.    [Calcium carbonate (A. R.) was used at 5 gm. per litre of the medium.]

A number of 250 c.c. Erlenmeyer flasks received 25 c.c. each of the above medium and about 0·25 gm. of calcium carbonate of known purity, the carbonate being weighed out accurately.    The flasks were inoculated with a rich culture of the Azotobacter.    The culture was obtained by growing the organism on agar media in 9 inch petri plates by the cellophane technique (Bhaskaran, *et al*, 1935).    The growth thus collected was shaken up with sterile water containing glass beads (for dispersion) and a uniform suspension obtained.    The cellophane technique was used for obtaining the culture so that none of the organic carbon of the medium was carried along with the culture.    2 c.c. of this suspension was used for inoculating each flask.    After inoculation, the flasks were incubated at 30° C. for varying periods of time.

Samples were taken at convenient intervals and analysed for the various constituents.    The results have been presented in Tables IV and V.

It may be seen from the results that the sugar was used up by Azotobacter comparatively slowly in spite of the heaviness of the inoculum.    This is significant in view of the observations made by Bhaskaran and Subrahmanyan (*loc. cit.*) where working with the mixed flora under the same conditions, it was found that the sugar was all used up in the course of the first four days. In the case of the mixed flora, it is probable that the other organisms (chiefly

the acid producers, Bhaskaran, 1936) are largely responsible for the rapid destruction of the sugar.

TABLE IV. *Distribution of Carbon.*

| Time in days | Organic carbon (in mg.) in 25 c.c. of medium | | | | Lost as gas (mg. of carbon) |
|---|---|---|---|---|---|
| | Total | Present as sugar | Present in slime and bact. cells | Present in supernatant | |
| 0 | 92·9 | 92·0 | 0·5 | 92·4 | Nil |
| 3 | 88·7 | 70·1 | 9·8 | 78·9 | 4·2 |
| 6 | 76·0 | 64·9 | 10·5 | 65·5 | 16·9 |
| 10 | 48·0 | 28·7 | 12·0 | 36·0 | 44·9 |
| 14 | 30·0 | Nil | 15·7 | 14·3 | 62·9 |
| 18 | 31·6 | ,, | 15·6 | 16·0 | 61·3 |
| 22 | 22·1 | ,, | 16·1 | 6·0 | 70·8 |
| 26 | 17·8 | ,, | 16·2 | 1·6 | 75·1 |

TABLE V. *Distribution of Nitrogen.*

| Time in days | Nitrogen (in mg.) in 25 c.c. of medium | | | C–N ratio of slime and bact. cells |
|---|---|---|---|---|
| | Total | In slime and bacterial cells | In the supernatant | |
| 0 | 0·14 | 0·04 | 0·10 | 14·25 |
| 3 | 0·43 | 0·33 | 0·10 | 29·30 |
| 6 | 0·95 | 0·82 | 0·13 | 12·80 |
| 10 | 1·07 | 1·03 | 0·04 | 11·75 |
| 14 | 1·20 | 1·09 | 0·11 | 14·30 |
| 18 | 1·24 | 1·12 | 0·12 | 13·90 |
| 22 | 1·28 | 1·24 | 0·06 | 12·80 |
| 26 | 1·22 | 1·14 | 0·08 | 14·20 |

Till the tenth day, the major part of the organic carbon in solution could be largely accounted for by the sugar present in the medium. There is no indication to show that during the first ten days (when the major part of the nitrogen fixation has taken place) the products of fermentation have been utilised for nitrogen fixation.

This is further supported by the following experiment. When the sugar had completely disappeared, the supernatant containing the products of fermentation was separated and inoculated with a fresh culture of Azotobacter. In this there was no further fixation of nitrogen. From this it would appear that the mechanism of carbon utilisation by the mixed flora of the soil for nitrogen fixation is different from that of Azotobacter.

The results also show that the major part of the nitrogen fixed could be accounted for by that present in the slime and bacterial cells ; the fixed nitrogen in solution being very little.

The growth capacity of the organism and its ability to form living bacterial cells and slime has also been studied by the procedure outlined before and the results are presented in Table VI.

TABLE VI.

*Growth in Relation to Intake of Carbon and Fixation of Nitrogen.*

| Time in days | Bacterial count in $\frac{\text{millions}}{\text{c.c.}}$ | Dry matter of cells and slime (in mg.)* | Organic carbon of cells and slime (in mg.) | Organic nitrogen of cells and slime |
|---|---|---|---|---|
| 0 | 61·0 | 2·4 | 0·5 | 0·04 |
| 3 | 90·1 | 25·3 | 9·8 | 0·33 |
| 6 | 151·3 | 36·0 | 10·5 | 0·82 |
| 10 | ·· | 38·0 | 12·0 | 1·03 |
| 14 | 190·5 | 36·6 | 15·7 | 1·09 |
| 18 | 192·5 | 38·6 | 15·6 | 1·12 |
| 22 | 181·0 | 36·5 | 16·1 | 1·12 |
| 26 | ·· | 39·7 | 16·2 | 1·14 |

* Correction for the residual $CaCO_3$, which separates along with the cells and slime, has been made.

From the results it can be seen that there is a close correlation between the dry matter and organic carbon of cells and slime throughout the period

of observation. In the early stages (first 3–4 days) there is not a corresponding increase in the nitrogen content of cells and slime. More of carbon seems to have been stored in the cells and slime in the first three days resulting in a high C–N ratio. Subsequently, the C–N ratio adjusts itself to the initial level. This would suggest that the carbohydrate material formed in the early stages has some bearing on the mechanism of fixation. More information is needed on this point before any definite conclusion can be drawn. It would be interesting in this connection to separate the cells from the slime and to find their individual C–N ratios.

*Discussion.*

The present enquiry has brought to light certain important aspects of the carbon metabolism of nitrogen fixers in nature and their relation to that of Azotobacter. It has also indicated some promising lines of future research on the mechanism of nitrogen fixation by Azotobacter, especially on the carbon side.

Previous researches (Bhaskaran and Subrahmanyan, *loc. cit.*) have shown that in presence of the mixed flora of the soil—which represents the natural conditions, the immediate products of decomposition are largely utilised for the fixation of nitrogen. During fixation of nitrogen by *Azotobacter chroococcum* in sugar media, there is no evidence to show that the products of fermentation are used up for nitrogen fixation. The major part of the fixation takes place even while the sugar is present in the medium. The mechanism of sugar utilisation for fixation of atmospheric nitrogen in the soil (by the mixed flora) is different from that of Azotobacter. This is an instance to show how the pure culture studies fail to explain the mechanism of soil biological phenomena. In biological nitrogen fixation in soil, the organism which is mostly associated in the process—Azotobacter—behaves in an entirely different manner from that of the mixed flora of the soil. In soil biological processes there is great need for studying the micro-organisms as a soil group—mixed flora—rather than attempt at a direct application of pure culture studies with single organisms.

The results presented in this paper are also of great scientific importance. They have indicated that a more detailed study of the carbon-nitrogen relationships of the slime and bacterial cells in the early stages and the nature of the polysaccharide material that constitute the tissues and its relation, if any, to nitrogen fixation might throw useful light on some of the till now obscure aspects of the mechanism of the process in Azotobacter. It will also be interesting in view of the above observations to study the rôle, if any, that the mucilaginous material plays in fixation,

Further work on the foregoing and allied aspects of the problem are in progress and will form the subject of later communications.

*Summary.*

(1) During decomposition of glucose by *Azotobacter chroococcum* there is no evidence to suggest that the immediate products of fermentation of the sugar are used up in nitrogen fixation. The major part of the fixation takes place even while the sugar is present in the medium.

(2) The water soluble products left after the complete disappearance of sugar, when inoculated with fresh culture of Azotobacter do not fix any nitrogen.

(3) From these and other evidence, it has been concluded that the mechanism of fixation of nitrogen in the soil is different from that by Azotobacter alone.

(4) In the early stages of sugar decomposition by Azotobacter correspondingly more of carbon is fixed in the slime and bacterial cells than nitrogen, the C–N ratio of the cells and slime being very high. Later on the ratio adjusts itself to the initial level. There is close correlation between growth of the organism and nitrogen fixation.

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# THE LIFE-HISTORY OF *RANUNCULUS SCELERATUS* LINN.

By Bahadur Singh.

*(From the Department of Botany, Agra College, Agra.)*

## 1. Introduction.

A FAIR amount of work has already been done on the morphology of the Ranunculaceæ. Representatives from all the divisions and tribes have been worked out, but the genus *Ranunculus* itself has not received the attention it deserves. Since this is usually considered to be one of the most primitive genera of the dicotyledons, and *Ranunculus sceleratus* probably the most primitive species of the genus (Kumazawa, 1930), I started some work on this plant in the hope of finding something of value in its morphology from the systematic point of view.

## 2. Material and Methods.

To start with, some embedded material and prepared slides were kindly handed over to me by Dr. P. Maheshwari and Mr. B. L. Gupta to whom my sincere thanks are due. Later on some more material was fixed in Nawaschin's fluid and formalin-acetic-alcohol both of which gave good results. Slides were stained in Iron-alum hæmatoxylin with a touch of fast green. As recommended by Gates (1925) Delafield's hæmatoxylin was used for the study of some phases of microsporogenesis. Some prepared slides of a cultivated species of *Ranunculus* (*R. muricatus* L.[1]) were also kindly passed on to me by Dr. P. Maheshwari for comparison.

## 3. Historical.

The mass of literature on the Ranunculaceæ has been very ably reviewed during the recent years by Schürhoff (1926) and Schnarf (1927 and 1931). I shall, therefore, briefly deal only with the work done on the embryology of the genus *Ranunculus*.

Mottier (1895) worked on several members of the Ranunculaceæ among which were three species of *Ranunculus*, *i.e.*, *R. abortivus*, *R. recurvatus* and *R. septentrionalis*. There are one to several archesporial cells in the nucellus. A tetrad of four megaspores is formed of which the chalazal gives rise to a normal eight-nucleate embryo sac. The large size of the antipodal cells is specially noteworthy.

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[1] I am thankful to the Forest Botanist, Dehra Dun, for the identification.

Coulter (1898) published a detailed account of the life-history of *R. septentrionalis*, *R. multifidus* and *R. abortivus*. The anther tapetum is said to be variable in origin, sometimes arising from the sporogenous tissue, and sometimes from the primary parietal layer. The archesporial tissue in the ovule consists of 1–13 cells in *R. septentrionalis*. In some cases several embryo sacs develop in the same ovule, but only one of them attains maturity. On account of the downward and one-sided development of the embryo sac the antipodals are frequently thrust to one side. The endosperm is free nuclear and sometimes the fusion nucleus is said to divide even before the fusion of the gametes or the entry of the pollen tube in the embryo sac.

Guignard[2] (1906) found double fertilisation in *R. flamula* and *R. cymbalaria*.

Huss[2] (1906) published a monograph on the morphology and physiology of the antipodal cells in which he states that occasionally two-nucleate antipodal cells are found in *R. repens* and *R. montanus*.

Schürhoff[2] (1915) found that the endosperm nuclei of *R. acer* often undergo an abnormal increase in size and then divide amitotically.

Salisbury (1931) has recently studied the morphology and ecology of *R. parviflorus* and frequent references will be made to this paper in the text.

Marsden-Jones (1935), working on the life-history and pollination of *Ranunculus Ficaria*, states that there are two varieties of this species one with bulbils and the other without them. The former, named as *R. bulbifera*, is tetraploid ($4n = 32$) and is propagated by vegetative methods, while the latter is diploid ($2n = 16$) and produces normal viable seeds.

Metcalfe (1936) has investigated the embryogeny and seedling anatomy of *Ranunculus Ficaria*, a species with only one cotyledon. The embryo consists of a club-shaped mass of undifferentiated parenchymatous cells. One of the cotyledons is suppressed and the growing point arises laterally to, but embedded in the base of the functioning cotyledon.

### 4. *Floral Morphology and Organogeny.*

*Ranunculus sceleratus* is a winter annual, very commonly found here in moist places, specially by river banks. The flowering period extends from January to April after which the ripe achenes are all shed and the plant dries up due to drought.

The floral organs do not arise in usual acropetal succession, but in the following order :—sepals, stamens, petals and carpels. This is in complete agreement with the observations of Salisbury (1931) on *R. parviflorus*.

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[2] Quoted in Schürhoff (1926) and Schnarf (1927) ; the original papers were not available to me.

Serial sections of older flowers show that each of the five quincuncially arranged sepals is supplied by three separate vascular strands, which leave a single gap in the vascular cylinder.   Sometimes only one trace is given off in the beginning but it soon divides into three before entering the sepal.   The accounts of Smith (1926 ; 1928), Kumazawa (1930) and Salisbury (1931) on other species of *Ranunculus* are essentially similar.   The last named author concludes that the morphology, anatomy and physiological behaviour of the sepals emphasize the fact that they are really leaf-bases modified to serve as bud scales of the developing flower.

The petals (4–5 in number) are of a glossy type with a naked  nectary at the junction of the lamina and the stalk (Fig. 1) ; in *R. muricatus*, however, there is a ventral covering over the nectary (Fig. 2).   There is a single layer
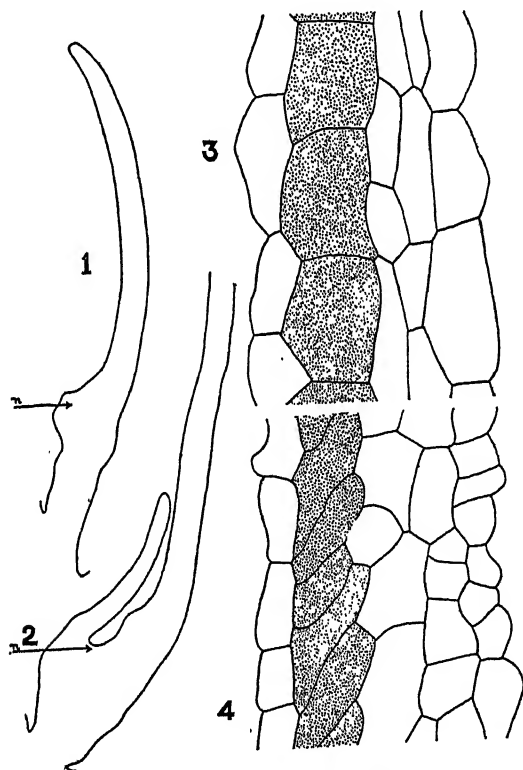


FIG.    1.—L.S. petal of *R. sceleratus* showing the naked nectary 'n'. $\times$ 149.

FIG.    2.—L.S. petal of *R. muricatus* showing the ventral covering of the nectary 'n'. $\times$ 53.

FIG.    3.—Part of Fig. 1., more highly magnified to show the presence of the single starch layer.  $\times$ 533.

FIG.    4.—Part of Fig. 2, more highly magnified, showing a single starch layer whose cells are obliquely oriented.  $\times$ 233.

of starch cells present below the ventral epidermis as seen in a longitudinal section of the petal (Figs. 3 and 4). The cells of this layer are larger than the other cells of the petal and are elongated at right angles to the epidermis—a fact also noted by Parkin (1935) in this species. In *R. muricatus*, however, the starch layer is oblique to the surface of the petal (Fig. 4). Parkin (1928 ; 1931) found that in all the species of this genus studied by him, the single layer of starch cells is oblique, and therefore, in a transverse section of the petal it appears to be more than one cell thick.

Only one vascular bundle enters the petal but it soon divides into three. Smith (1926) found the same in *R. hispidus* and Salisbury (1931) found one bundle in *R. parviflorus*, which divides into five strands below the nectary. The stamens are single trace organs like the petals but the strands supplying them do not branch. The carpels are also supplied originally by a single vascular bundle but this soon divides into three to form one dorsal and two ventral bundles.

### 5. Early Development of the Anther and the Formation of Wall Layers.

The young anther is oval in transverse section with a group of richly protoplasmic cells on each side as shown in Fig. 5. This condition is also found in *Lemna minor* (Caldwell, 1899) and *Limnophyton obtusifolium* (Johri, 1935), with the difference that in the last two cases such a stage is preceded by one showing a single group of densely staining cells which later becomes separated into two. In all the three plants mentioned above a plate of sterile cells now appears in between each group resulting in the usual four groups of archesporial cells in the anther (Fig. 6). As the development proceeds further they become more or less clearly marked out from the adjoining cells by their larger nuclei and more deeply staining cytoplasm.

The archesporial cells cut off a primary parietal layer towards the periphery which divides periclinally to form two layers of cells of which the inner directly becomes the tapetum, and the outer divides further to form an endothecium (Fig. 7), and two middle layers (Fig. 8). The sequence of divisions is thus comparable to that recorded by Asplund (1920) in the Valerianaceæ and Guèrin (1919) in the Labiatæ. In *Ranunculus parviflorus* there is only one middle layer (Salisbury, 1931).

Coulter's statement (1898, pp. 74, 75) on the origin of the tapetum is ambiguous. He says that " in some cases the whole of the tapetum seemed to be cut off from the periphery of the sporogenous tissue and in others its parietal derivation from the wall cells seemed equally clear." During recent years the tapetum is shown to have a parietal origin in so many Angiosperms
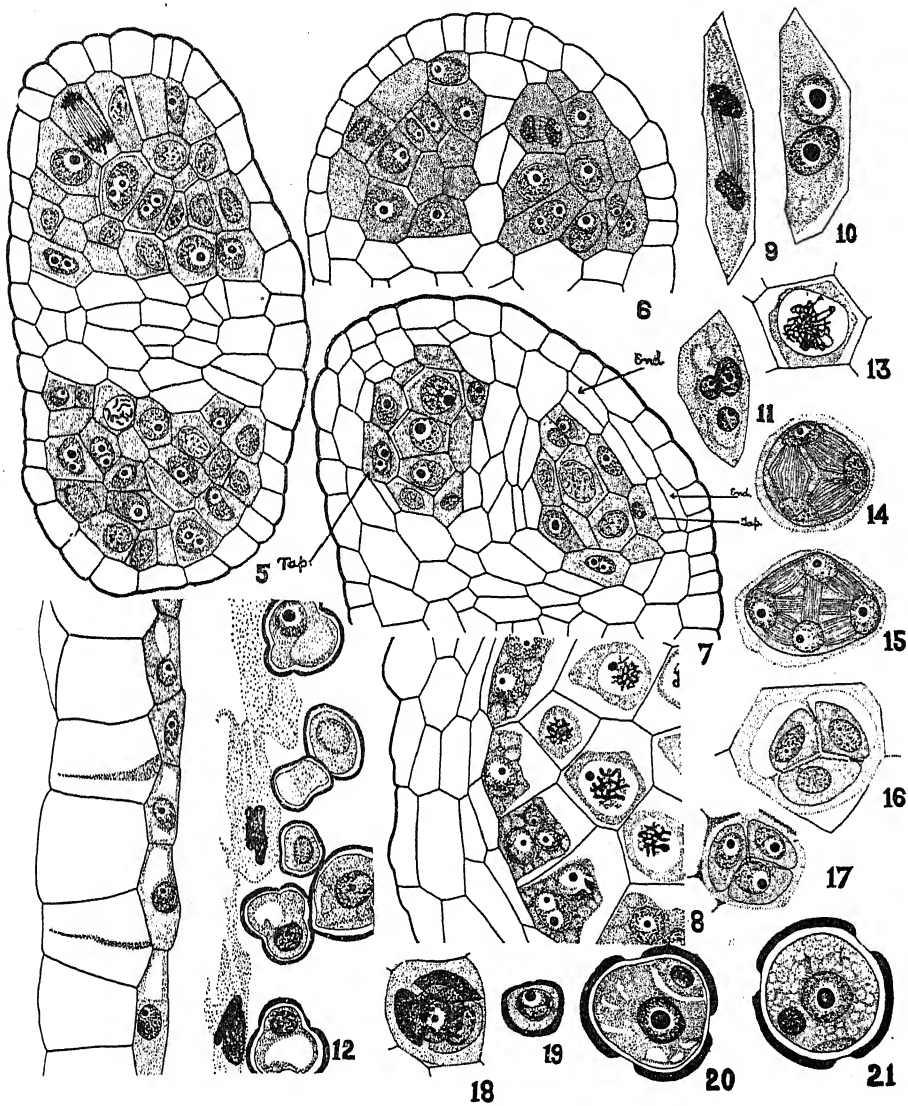
FIG. 5.—T.S. Anther, showing 2 groups of richly protoplasmic cells. $\times$ 640.

FIG. 6.—T.S. Part of the anther showing 2 groups of archesporial cells. $\times$ 640.

FIG. 7.—T.S. Part of the anther showing two anther lobes with sporogenous cells, tapetum and wall layers. $\times$ 640. (Tap $=$ Tapetum; End $=$ Endothecium.)

FIG. 8.—T.S. Part of the anther showing wall layers and mother cells preparing for reduction division. $\times$ 640.

FIGS. 9–11.—Tapetal cells. $\times$ 950.

FIG. 12.—L.S. Wall of the anther at the microspore stage, showing degenerated remains of the tapetum, the outer middle layer, the endothecium and disorganised epidermis (the inner middle layer has already disappeared). $\times$ 640.

FIG. 13.—Microspore mother cell in prophase of the first reduction division. The cytoplasm has contracted from the wall and the nucleus has considerably enlarged. $\times$ 950.

FIGS. 14–15.—Tetra-nucleate mother cells with spindles connecting the nuclei. $\times$ 950.

FIG. 16.—Microspore tetrad showing the ingrowth of the wedges from the special wall. The original mother cell wall is disappearing. $\times$ 950.

FIG. 17.—Tetrahedral tetrad showing special wall and remains of the original wall that has also thickened. $\times$ 950.

FIG. 18.—Tetrad of microspores of which two are degenerating. $\times$ 950.

FIG. 19.—Young microspore with thickened exine. $\times$ 950.

FIG. 20.—Two-celled pollen grain. $\times$ 950.

FIG. 21.—Two-nucleate pollen grain. $\times$ 950.

that any claim of a different origin will have to be strongly supported. Of course, the tapetal cells become much larger than those of the outer wall layers, and in their contents and staining reactions they show a great resemblance to the sporogenous cells. It may be this character that led Coulter to think that it is occasionally derived by the sterilisation of the sporogenous cells. The same remark applies to Swingle's[2] statement (1908) on *Myosurus*. As already mentioned and illustrated by Fig. 5, the tapetum in *R. sceleratus* is always derived from the primary parietal layer.

Coulter (1898) also states that in the species of *Ranunculus* investigated by him the tapetal cells remained uni-nucleate in many cases. Salisbury (1931) reports a many-nucleate tapetum in *R. parviflorus*. Cooper (1933) found a bi-nucleate tapetum in *R. fascicularis*. Clausen (1927) reports that in *R. aquatilis* the tapetal cells may become 1–4 nucleate and in *R. acris* they are bi-nucleate. I have noted that in *R. sceleratus* the nuclei of the tapetal cells divide mitotically (Fig. 9) at the time when the microspore mother cells are in synizesis. Most of them become bi-nucleate (Fig. 10) but in tangential sections of the anther (which give specially good view of the tapetum) I could occasionally see even three nuclei in some cells (Fig. 11). Degeneration of the tapetum starts at the microspore tetrad stage and there is no trace of it when the pollen grains have become bi-nucleate (see Fig. 12, where the tapetum shows an advanced stage of degeneration). Coulter (1898, p. 76) writes, "The disorganisation of the tapetum and wall layers begins early so that the mother cells become quite free in the loculus." The meaning of this statement is not quite clear to me, and his Fig. 6 to which he has referred in the text, shows no sign of degeneration in any of the wall layers including the tapetum. Moreover, at least in *R. sceleratus*, the mother cells never become free in the loculus.

In a few cases the tapetal cells were found to elongate and protrude inside the anther loculus so as to resemble the condition found by Clausen (1927) in *R. aquatilis*. The formation of a periplasmodium is not of a regular

occurrence, but two instances were seen in which tetrads of microspores were found embedded in a granular mass of cytoplasm which could not have been derived except from the tapetal cells.[3]

The endothecium develops the characteristic fibrous thickenings at maturity. It becomes the functional covering of the anther, since practically no trace of the epidermis is left towards the end (Fig. 12). Of the two middle layers the inner is the first to be absorbed and there is hardly any trace of it in anthers in which the microspores have just separated from the tetrads. But before this happens, its cells may occasionally increase in size and become filled with dense cytoplasm. The outer middle layer persists a little longer and is absorbed only after the pollen grains have become bi-nucleate. Occasionally the cells of this layer may also enlarge and become filled with dense cytoplasm (Fig. 12) before their final degeneration and absorption. This peculiar behaviour of the middle layers shows that they form a potentially nutritive jacket whose cells sometimes take up the tapetal function. Coulter and Chamberlain (1903, p. 36) state that in some cases in *Ranunculus* " one or two inner middle layers become prominent as a part of the tapetum, in others the outer ones may become a part of the endothecium ; and occasionally there is no disorganisation of the parietal layers."

### 6. *Microsporogenesis.*

As in other species of *Ranunculus* studied by Coulter (1898), the sporogenous cells divide only once or twice to produce the microspore mother cells. Their cytoplasm takes a lighter stain than that of the surrounding tapetal cells. As they prepare for the first reduction division, their nuclei enlarge and fill up the greater part of the space within the cell while the cytoplasm contracts away from the wall and is reduced to a thin layer round the nucleus (Fig. 13). The mother cell walls still remain in contact with one another and can be seen as very thin radiating structures in preparations stained with Delafield's hæmatoxylin or fast green. They are, however, gradually used up although their remains can still be traced up to the microspore tetrad stage (Figs. 16, 17 and 18).

While the first reduction division is in progress, the cytoplasm of the mother cell begins to secrete a special wall inside the original mother cell wall. It is clearly visible in slides stained with fast green or Delafield's hæmatoxylin, but is liable to escape notice in sections stained merely with iron-alum hæmatoxylin. The special wall (Figs. 14–18) increases considerably in thickness and is mostly found adhering to the cytoplasm, but sometimes a space

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[3] Whyte (1929) found that in exceptional cases the tapetum becomes "pseudoperiplasmodial" and its cells wonder inbetween the pollen grains.

might be seen between the two, the special wall becoming attached to the original mother cell wall (Fig. 16).

*Cytokinesis.*—The divisions of the microspore mother cells are simultaneous as in other plants of this family (see Schnarf, 1931, pp. 75 and 83). The arrangement of the microspore tetrads is either tetrahedral, isobilateral (Figs. 14–18) or sometimes decussate. In a tetra-nucleate mother cell six spindles are seen connecting all the four nuclei (Figs. 14 and 15). Cell plates appear in the equatorial region of these spindles, but they are transitory in nature. Such evanescent cell plates have also been reported by Yamaha (1926) in *Ranunculus*. Hereafter the spindle fibres disappear and cytokinesis occurs by furrows starting at the periphery of the tetra-nucleate mother cell opposite to the place formerly occupied by the transitory cell plates. The ingrowing furrows are followed closely by the sharp wedges from the special wall (Fig. 16) as described in *Lathræa clandestina* by Gates (1924). The furrows and the wedges finally meet in the centre of the tetra-nucleate cell dividing it into four uni-nucleate masses. The special wall described by Castetter (1925) in *Melilotus alba* is a bit different from the one found in the present case. He states that a callose wall originates inside the original mother cell wall and is secreted by the activity of the cytoplasm. Inside the callose wall the cytoplasm of the mother cell secretes another wall, the special wall, more refractive than the former. A third wall of this type is, however, absent in the present case. The walls of the young pollen grains begin to thicken even when they are enclosed within the special wall.

### 7. *Male Gametophyte.*

The young microspores are oval in shape and soon develop the usual exine and intine (Fig. 19). The nucleus moves towards one side of the cell and divides here to form the tube and the generative cells (Fig. 20), but the wall between the two nuclei disappears a little later (Fig. 21). Two-nucleate mature pollen grains have also been reported in other species of *Ranunculus* by Coulter (1898), but some other plants of this family—*Myosurus minimus* (Tschernoyarow,[2] 1926) and *Batrachium longirostre* (Riddle,[2] 1905)—have three-nucleate pollen grains. Coulter (1898) observed 15–30 germ pores in the pollen grains of the species of *Ranunculus* studied by him, but I have been able to find only 3 in *R. sceleratus* (Figs. 20 and 21).

### 8. *Degenerations.*

Often one, two (Fig. 18), three or all the four microspores of a tetrad may degenerate and sometimes degenerations are found even at more advanced stages up to the time of maturation of the pollen.

## 9. *Ovary and Ovule.*

The ovule appears as a naked outgrowth in the axil of the carpel (Fig. 22) which gradually curves upwards and inwards and finally encloses it (Fig. 23). Mottier (1895) and Salisbury (1931) have described the same method of development of the carpel in *R. abortivus* and *R. parviflorus*. An essentially similar condition is found in *Alchemilla arvensis* (Murbeck, 1901, p. 3, Fig. 1), *Boerhaavia diffusa* (Maheshwari, 1929), *Boerhaavia repanda* (Bhargava, 1932) and several members of the Alismaceæ (Eber, 1934). The mature carpel of *Ranunculus sceleratus* shows a notch on the ventral side, at the point where
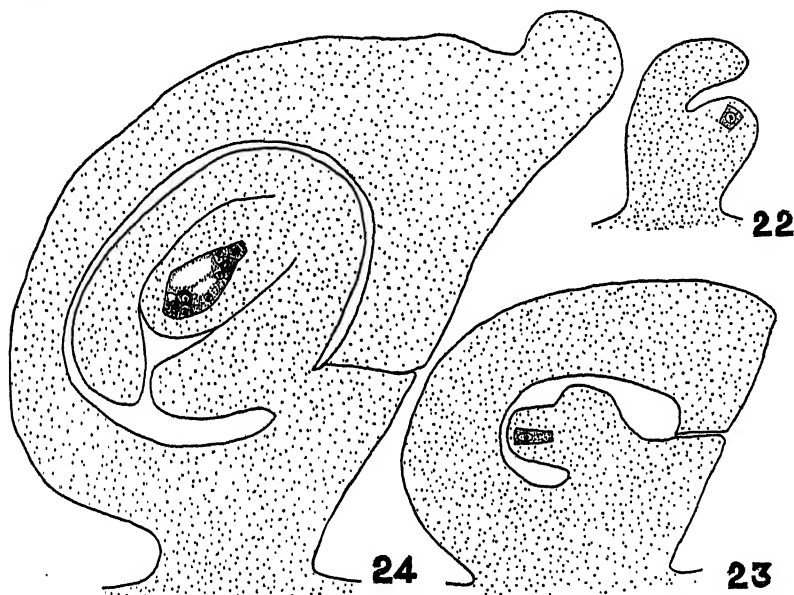


FIGS. 22–24.—Stages in the development of the carpel. × 233.

the fusion occurred (Fig. 24) and the epidermal cells of both the sides still remain distinct showing that an absolutely complete fusion is never attained. An essentially similar fusion on the ventral side of the carpel takes place in *R. muricatus* and the epidermal cells of both sides are always distinct.

The fully grown ovule is hemitropous (Fig. 24) with a single integument which is usually 4–5 cells thick. The condition in the Ranunculaceæ is extremely variable with regard to the number of integuments present in the ovule, but all the species of the genus *Ranunculus* have so far been reported to have only one integument.

## 10. *Megasporogenesis.*

Usually there is a single hypodermal archesporial cell (Fig. 25) in the nucellus, but sometimes two (Fig. 26) or even three such cells may be present.
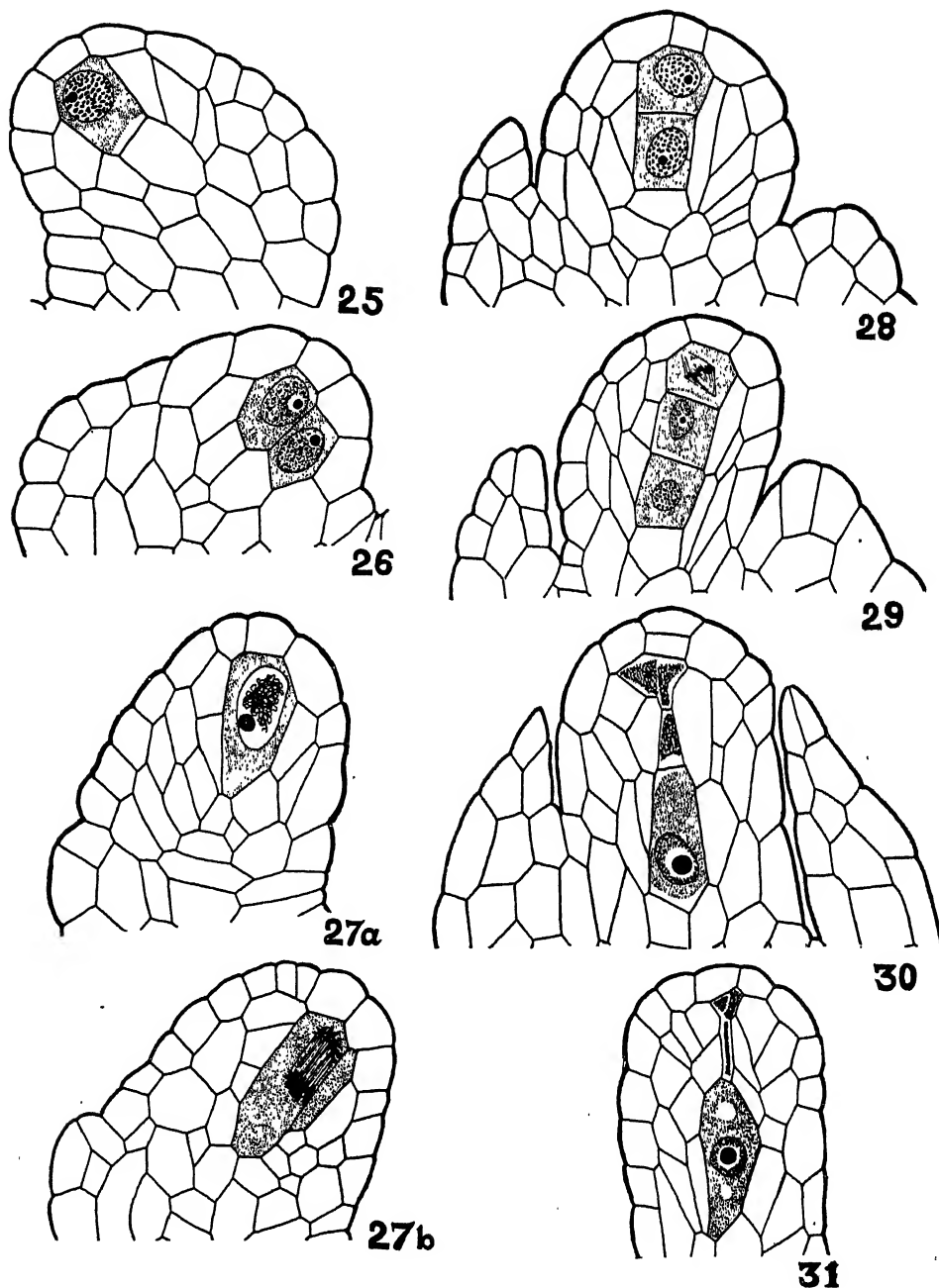
FIG. 25.—L.S. Ovule with a single hypodermal archesporial cell. $\times$ 853.

FIG. 26.—L.S. Ovule showing two hypodermal archesporial cells. $\times$ 853.

FIGS. 27*a* & 27*b*.—Adjacent sections of the same nucellus with one mother cell in each, the former in synizesis and the latter in telophase. $\times$ 853.

FIG. 28.—Megaspore mother cell divided into two daughter cells. Note the bigger size of the lower cell. × 853.

FIG. 29.—Tetrad formation; lower cell already divided; upper in process of division. × 853.

FIG. 30.—T-shaped tetrad of megaspores; chalazal megaspore has enlarged. Note the nucellar cells on the sides in this and the next (Fig. 31) encroaching upon the degenerating megaspores. × 853.

FIG. 31.—Functioning megaspore. × 853.

In one instance a megaspore mother cell was found mounted on top of three cells which appeared to have an archesporial character. This agrees with the fact that a multi-cellular archesporium is of general occurrence in the family (see Schnarf, 1927, p. 78).

The primary archesporial cell functions directly as the megaspore mother cell. Sometimes two mother cells are found inside the same nucellus (Figs. 27*a*, 27*b* represent two consecutive sections of the same ovule). As pointed out by Dahlgren (1927) a periclinal division of the epidermal cells of the nucellus takes place so frequently in this family that one may easily get the impression of the presence of wall cells when such is really not the case. A deceptive appearance may also be caused in an entirely different way to be mentioned later.

The megaspore mother cell enlarges considerably. Its nucleus is always situated in the upper part of the cell, so that, of the two dyad cells resulting from the first division, the upper is always smaller than the lower (Fig. 28). Both divide again, but Fig. 29 shows that the division in the upper cell often lags behind, a fact also noted by Mottier (1895) in *Delphinium tricorne*. It is to be noted that the spindle in the upper cell frequently lies in a plane oblique (Fig. 29) or transverse to that of the lower. The megaspore tetrads are, therefore, generally T-shaped (Figs. 30, 31), but linear tetrads are also found occasionally. Mottier (1895) states that in *R. abortivus* sometimes no wall is formed between the two daughter nuclei formed after the division of the upper dyad cell and, therefore, there is a row of only three cells of which the uppermost is bi-nucleate.

Salisbury's recent statement (1931, p. 561) that a wall cell is occasionally cut off in *R. parviflorus* needs to be critically considered.[4] The figure (Plate XVIII, Fig. 3) cited in support of this statement really shows a T-shaped tetrad of megaspores directly abutting on the epidermis. Souegès (1912, Fig. 37) gives an exactly similar figure of *Adonis autumnalis* and interprets it quite correctly as a megaspore tetrad.

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[4] He writes that "The ovule of which a median section is shown in PL. XVIII, Fig. 3, shows a megaspore mother cell which has undergone the first division, and between these and the epidermis a primary parietal cell which has divided into two by a vertical wall . . . . Whether the production of primary parietal cells by *R. parviflorus* is of general occurrence or not, the available material in an appropriate stage of development does not permit of answering."

Degeneration of the upper three megaspores seems to take place very quickly, and it is, therefore, not easy to find a tetrad with all the four megaspores in a good condition (Fig. 29). The cells of the nucellus on both sides of the degenerating megaspores encroach upon them and come closer towards one another reducing the degenerating megaspore to just a thin streak as shown in Figs. 30, 31. Eventually, all the remains of the degenerating megaspores disappear and the cells of the nucellus completely close up at the top. Mottier (1895, Figs. 8 ; 28) also found this type of closing up of the nucellar cells in *Delphinium tricorne* and *Aquilegia canadensis*.

## 11. Embryo Sac.

The two-nucleate embryo sac (Fig. 32) formed after the division of the functioning megaspore appears to be deep-seated due to the secondary closing up of the nucellar tissue as explained above. As it increases in size, these cells are crushed (see Figs. 32–37) and used up, so that it comes to lie just below the nucellar epidermis which divides periclinally and becomes two-layered at the top. Both the nuclei divide simultaneously. The spindle in the chalazal part of the embryo sac is parallel to the longitudinal axis of the nucellus ; while the upper is at right angles to it (Fig. 33). Fig. 34 shows an exceptionally large four-nucleate embryo sac which may be the outcome of better nutrition. All the four nuclei of the four-nucleate embryo sac again divide simultaneously (Fig. 35). In this division, the spindles of the micropylar end are arranged at right angles to each other while those at the chalazal end are obliquely oriented to the long axis of the embryo sac (Fig. 35). After the division is completed, the nuclei lie close to each other in pairs for some time (Fig. 36). From the position of the spindles, one would judge that the egg and the upper polar nucleus on the one hand, and the two synergids on the other hand are formed from the sister nuclei, and such is the case in most other Angiosperms in which mitotic figures have been seen (cf. *Boerhaavia diffusa*, Maheshwari, 1929), but Schürhoff (1928) thinks differently. He has put forward the view that one synergid and the egg (which are, according to him, derived from the division of the same nucleus) form one archegonium, while the other synergid with the upper polar nucleus forms a second archegonium. My observations on *R. sceleratus* support the older view of Porsch (1907) which is based on the idea that the two synergids are sisters to each other and so are the egg and upper polar nucleus. The synergids are rather ephemeral in *R. sceleratus* although in *R. acer* (Schürhoff,[2] 1915) they persist till the time of fertilisation. Osterwalder[2] (1898) in *Aconitum nepellus* and Persidsky[2] (1914) in *Delphinium elatum* have reported fertilisation of the synergids.
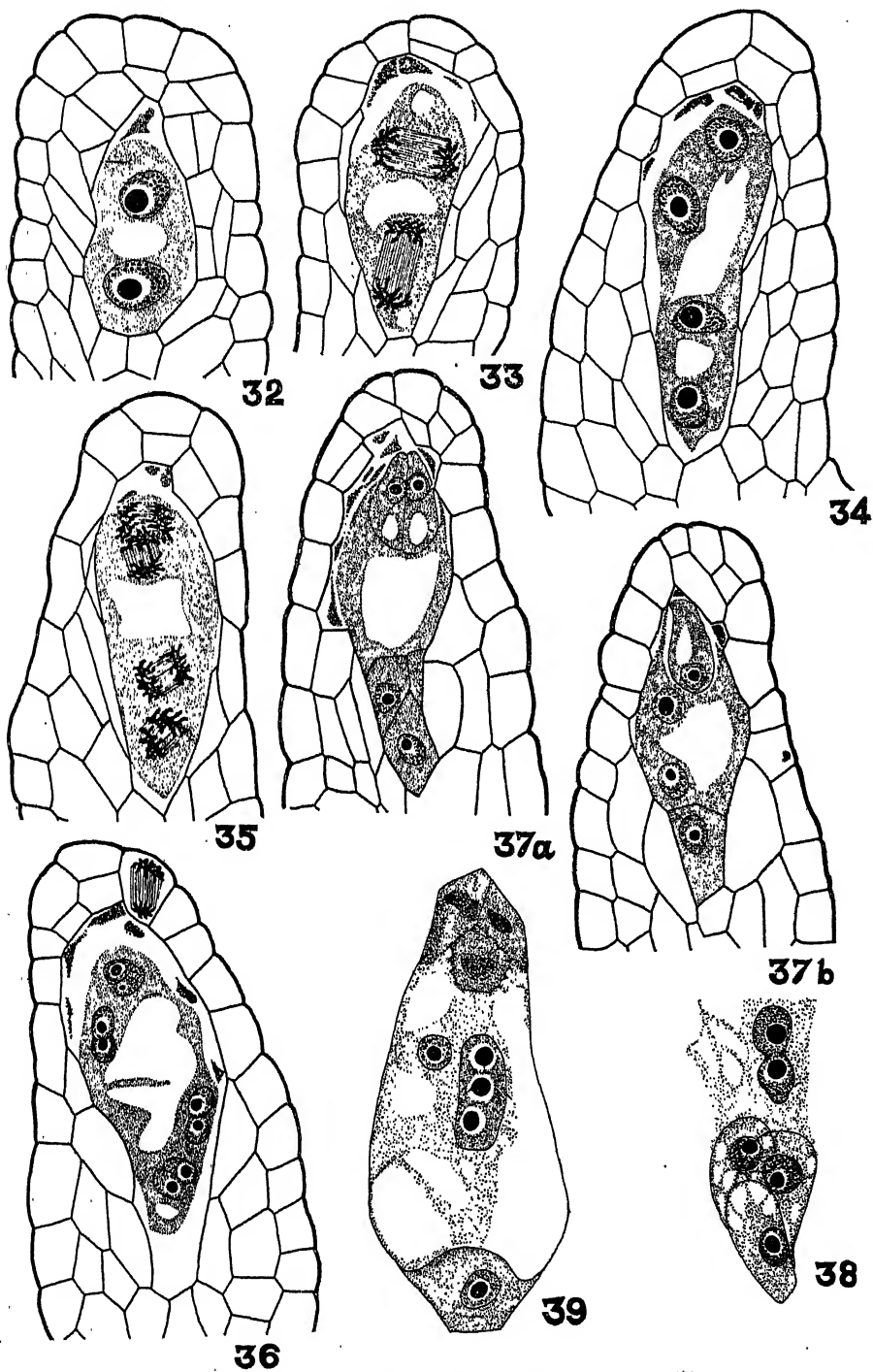
FIG. 32.—Two-nucleate embryo-sac. $\times$ 853.
FIG. 33.—Division of the two nuclei. $\times$ 853.

Fig.  34.—An abnormally large four-nucleate embryo sac. $\times$ 853.
Fig.  35.—Embryo sac showing division of four nuclei. $\times$ 853.
Fig.  36.—Embryo sac with eight free nuclei. $\times$ 853.
Figs. 37a & 37b.—Adjacent sections of the nucellus showing a mature embryo sac. $\times$ 853.
Fig.  38.—Part of embryo sac showing enlarged antipodal cells. $\times$ 853.
Fig.  39.—Abnormal embryo sac. For explanation see text. $\times$ 853.

The antipodal cells are very conspicuous and persistent.   One of these cells lies in the extreme end of the embryo sac ; while the other two are situated on either side just above it.   At the time of division of the primary endosperm nucleus, they are more prominent and occupy a greater space than the egg apparatus (Fig. 38).   They do not multiply in number, but in one instance one of the three antipodal cells was observed to be bi-nucleate.   The uni-nucleate condition is also found in all other species of *Ranunculus* (so far studied) except *R. repens* and *R. montanus* where some cases of bi-nucleate antipodal cells have also been cited.   An increase in the number of antipodal nuclei undoubtedly takes place in some other plants of this family, while in still others there is an increase in the number of the antipodal cells themselves ; e.g., *Hepatica* in which as many as 25 of them have been counted (Coulter and Chamberlain, 1903) and *Trautvettaria* (Schürhoff, 1926) in which 11 have been reported.   Degeneration of the antipodal cells  in *R. sceleratus* does not start until many free nuclei have been formed in the endosperm.

## 12.  Endosperm.

Development of the endosperm starts much before the division of the egg.   At least, in the earlier stages the divisions are simultaneous and a large number of free nuclei is produced.   Wall formation starts at the periphery. Coulter (1898) says that, in the species of *Ranunculus* studied by him, endo-sperm formation sometimes begins even before fertilisation or the entry of the pollen tube into the embryo sac.   Nevertheless, his Fig. 58 (showing part of the embryo sac of *R. multifidus*), cited in support of the above, appears to me to be a post-fertilisation stage.

## 13.  Abnormality.

An abnormally large embryo sac was found inside an ovule (Fig. 39).   The egg apparatus had the usual egg and the two synergids all in an advanced stage of degeneration.   At the opposite end, there was only a single antipodal cell and in the centre were two polar nuclei.   One of these was very large and oblong ; it had three nucleoli, while the other was of average size with only one nucleolus in it.   It appears that the larger nucleus was formed by the fusion of the lower polar nucleus and two of the antipodal nuclei.   A somewhat similar case was found by Murbeck[2] (1901) in the parthenogenetic

species of *Alchemilla* where all the three antipodal nuclei and even the synergids may move towards the centre, resulting in groups of three, four, or five polar nuclei surrounded by a common mass of cytoplasm.

### *Conclusion and Summary.*

A detailed theoretical discussion of the results would be out of place in a paper like this, specially since this work on *R. sceleratus* does not reveal anything strikingly different from that of other species previously investigated.

Observations on the organogeny of the flower have not been made by most of the authors who have worked on this genus. The floral organs do not arise in the usual acropetal succession but in the following order :—sepals, stamens, petals and carpels (*cf., R. parviflorus*; Salisbury, 1931).

The vascular supply to the floral organs does not present any features of particular interest. As in other species of this genus, the sepals are three-trace organs ; the stamens receive a single trace and so do the petals but here the vascular bundle soon forks into three. The carpel has one dorsal and two ventral bundles.

A critical study of the development of the anther shows that the tapetum, as well as the other wall layers are parietal in origin. Coulter (1898) reported that in *R. septentrionalis*, the tapetum originates by the sterilisation of the sporogenous cells, but Bonnet (1912) showed that such reports were due to false resemblance between the tapetum and the spore mother cells at the time of reduction divisions. The behaviour of middle layers is uncommon since their cells often increase in size, simulating the tapetum in appearance and probably functioning similarly.

The divisions of the microspore mother cells are simultaneous and cytokinesis takes place through furrowing. The pollen grains are shed at the two-nucleate stage.

The ovules are hemitropous with a single massive integument. The number of archesporial cells in the nucellus is from one to three. It is rather striking that in such a primitive genus like *Ranunculus* wall cells are not cut off. Salisbury's (1931) statement that a wall cell is sometimes cut off in *R. parviflorus* is not borne out by his figure in which the so-called wall cell really appears to be the two topmost megaspores of a T-shaped tetrad.

The embryo sac develops quite normally and is eight-nucleate. The synergids are ephemeral but the antipodals are very persistent and conspicuous as in other members of the family.

It is concluded that embryologically the family Ranunculaceæ does not display any well recognised primitive characters except the presence of a multicellular archesporium in the nucellus.

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# A NEW SPECIES OF THE GENUS *LEVINSENIELLA* FROM THE JACK SNIPE, *GALLINAGO GALLINULA*.

By Makund Behari Lal.

*(From the Department of Zoology, Lucknow University.)*

THE Genus *Levinseniella* was established by Stiles and Hassall (1901) (which paper I have not seen but its reference is made in Sprehn's *Lehrbuch der Helminthologie*) for forms like *Distoma brachysomum* Creplin and *Levinsenia brachysomum* Stossich. Several species of the genus have since been reported but some of them, for lack of adequate description, are merely species in name. The following have been considered as important species of the genus *Levinseniella* :

1. *Levinseniella brachysoma*......Type species.
2. *Levinseniella propinqua.*
3. *Levinseniella pellucida.*
4. *Levinseniella howensis.*
5. *Levinseniella minuta.*
6. *Levinseniella adunca.*
7. *Levinseniella squatarolæ.*
8. *Levinseniella cruzi.*
9. *Levinseniella jagerskioldi.*
10. *Levinseniella similumus.*

The present communication adds another species to the genus, *Levinseniella*. The work was carried out under the supervision of Dr. G. S. Thapar to whom the author is grateful for his kind guidance. The author also wishes to acknowledge his thanks for the help received from Dr. A. C. Chatterji in translating some German literature on the subject.

## Levinseniella indica *N. Sp.*

About half a dozen specimens were obtained from the bursa fabricii of the Jack snipe, *Gallinago gallinula* at Lucknow. They were of white colour and exhibited no movements but under slight pressure of the coverglass their movements could be watched under the microscope. The anterior half of the body of these trematodes appears to be more motile than the posterior region.

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The trematodes are roughly triangular in shape with blunt apex. The broad base of the triangle is curved at its ends meeting the sides which gradually taper towards the anterior end. The body is covered over with minute spines upto the level of ventral sucker. The length of the specimen is ·93 mm. and its maximum breadth, a little in front of the posterior base, is ·5 mm.

The oral sucker is subventral, strongly developed and measures ·1 mm. × ·12 mm. in diameters. The ventral sucker is smaller than the oral sucker and is situated at a distance of about ·67 mm. from the anterior end. It is roughly circular and measures ·08 mm. × ·078 mm. in diameters.

The oral sucker leads into the pre-pharynx which is very short and thin-walled and measures ·02 mm. in length. This leads into a bulbous pharynx with thick muscular walls. It measures ·056 mm. × ·055 mm. The œsophagus is ·22 mm. long and divides into the two intestinal cæca at its posterior end at a distance of ·42 mm. from the anterior end of the body
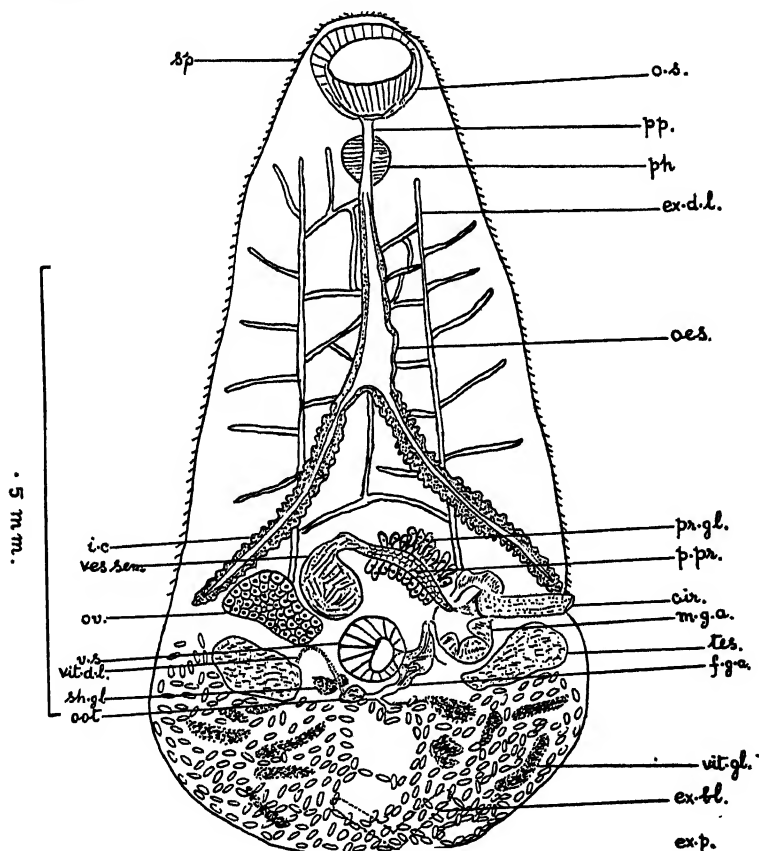


Fig. 1.—*Levinseniella indica* n. sp., showing the disposition of the internal organs.

and ·25 mm. from the ventral sucker. The intestinal cæca extend upto the level of the anterior margin of the ventral sucker. The cæca have a narrow lumen and thick walls.

The excretory system is not quite clear owing to an extremely large number of eggs filling up the posterior half of the body. The excretory pore is terminal and leads into a V-shaped bladder which is short and extends only upto the level of the vitellaria. Two longitudinal excretory ducts with anastomosing branches are seen running in the anterior half of the animal. They open into the limbs of the excretory bladder.

The testes, two in number, are situated more or less symmetrically about the level of the posterior margin of the ventral sucker. The right testis is smaller than the left and measures ·105 mm. × ·058 mm. The left testis measures ·12 mm. × ·06 mm. The vesicula seminalis is a retort-shaped body lying just in front of the ventral sucker, and much behind the intestinal bifurcation. It measures ·1 mm. × ·065 mm. in size and ends in a tubular pars prostatica, about ·135 mm. long, which is surrounded by a large number of prostate-gland cells. The prostate gland cells lie free in the space surrounding the pars prostatica. The pars prostatica leads into a cylindrical cirrus, ·1 mm. in semi-contracted state as seen in the specimen. The cirrus bears very small spines. A cirrus-sac is absent in these trematodes. The cirrus lies normally in the male genital atrium, situated on the left side, which is an elliptical structure with 4–5 muscular thickenings on its sides. The male genital opening is situated at about ·09 mm. from the ventral sucker.

The ovary lies anterior to the right testis on the right side of the ventral sucker and slightly in front of it. It is ellipsoidal and measures ·105 mm. × ·06 mm. The ootype complex with shell-gland cells occupies the triangular space between the ventral sucker and the testis and the ovary. A small yolk reservoir is also present. The uterus arises on the left side of ootype and is confined to the post-testicular region. A very large number of small eggs with thick shell and without filaments are present. They measure ·017 mm. × ·006 mm. The metraterm lies in the female genital atrium which is a thick walled structure lying dorsally and laterally to the ventral sucker on the left side.



FIG. 2. *Levinseniella indica* n. sp., eggs.

·05 mm.

The vitelline glands consist of about a dozen compact bodies and they lie in groups of 5 or 6 just behind the testes. The vitelline ductules all join to form two main lateral vitelline ducts. The right vitelline duct forms a

loop near the ovary and the left one comes straight and they both finally open into the öotype.

To sum up, the species may be characterised thus :

Distomes with body pear-shaped or in the form of a triangle with blunt apex, oral sucker larger than the ventral ; prepharynx very short, intestinal cæca stop at the level of the anterior margin of the ventral sucker and are thick-walled with narrow lumen ; excretory bladder V-shaped with terminal excretory pore ; testes, two, lie behind the ventral sucker, at the same level, they are more or less symmetrical, vesicula seminalis retort-shaped, pars prostatica and prostate gland-cells present, male genital atrium with 4–5 thickenings of its wall, cirrus spiny ; ovary anterior to testis on the right side of the ventral sucker, yolk reservoir present, the female genital atrium thick-walled and close to ventral sucker ; uterus post-testicular, eggs thick-shelled ; vitelline glands in groups of 5–6 follicles behind testes.

The characters of the species point out that the form belongs to the genus *Levinseniella*. But the present form differs from all the species of the genus. It differs from *L. brachysoma* in having a shorter prepharynx, much longer pars prostatica and smaller eggs. From the species *L. propinqua* it differs in having intestinal cæca extending upto the level of the anterior margin of the ventral sucker, in having ovary a little in front of the ventral sucker, in having testes at the level of the posterior margin of the ventral sucker and in having smaller eggs. From *L. pellucida* it differs in having a retort-shaped vesicula seminalis and longer pars prostatica. From *L. howensis* it differs in having a very small prepharynx, ovary and testes of almost equal size, and well-developed genital atrium. From *L. minuta* it differs in having a prepharynx and much smaller eggs. The species *L. adunca, L. squatarolæ, L. cruzi, L. jagerskioldi* and *L. similumus* all possess a cirrus-sac and, therefore, do not appear to conform to the generic diagnosis of *Levinseniella*. Further observations on these species may, perhaps, show their possible relationship with the genus *Maritrema*. The species described in the present communication, therefore, stands out as a distinct form and is named *Levinseniella indica* n. sp.

### LIST OF ABBREVIATIONS USED IN THE FIGURES.

| | | |
|---|---|---|
| *cir.* | .. .. | Cirrus. |
| *e.* | .. .. | Eggs. |
| *ex. bl.* | .. .. | Excretory bladder. |
| *ex. d. l.* | .. | ..Lateral excretory duct. |
| *ex. p.* | .. .. | Excretory pore. |
| *f.g.a.* | .. .. | Female genital atrium. |
| *i.c.* | .. .. | Intestinal Cæca. |
| *m.g.a.* | .. .. | Male genital atrium. |
| *oes.* | .. .. | Oesophagus. |
| *oot.* | .. .. | Öotype. |
| *o.s.* | .. .. | Oral sucker. |
| *ov.* | .. .. | Ovary. |
| *p. pr.* | .. .. | Pars prostatica. |
| *ph.* | .. .. | Pharynx. |

| *pp.* | .. | .. | Prepharynx. | *v.s.* | .. | .. | Ventral sucker. |
| *pr. gl.* | .. | .. | Prostate gland-cells. | *ves. sem.* | | .. | Vesicula seminalis. |
| *sh. gl.* | .. | .. | Shell gland-cells. | *vit. d. l.* | .. | .. | Lateral vitelline duct. |
| *sp.* | .. | .. | Spines. | *vit. gl.* | .. | .. | Vitelline glands. |

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# CONTRIBUTIONS TO OUR KNOWLEDGE OF THE FRESHWATER ALGÆ OF NORTHERN INDIA.

## I. Oedogoniales.

By M. S. Randhawa, M.Sc., I.C.S.

(*Saharanpur*)

### Group 5. Oedogoniales.

### *Genus Oedogonium* Link.

### *Genus Oedogonium.*

This alga is found in freshwater ponds, lakes and streams, nearly all over the world. The filaments have a well-developed basal cell by means of which they get attached to sticks and stones. The filaments are unbranched and the cells are usually cylindrical or barrel-like in appearance. The genus was described by Link in 1820.

A. Section *Dioica nannandria.*—

1. *Oedogonium striatum* sp. nov. *Idioandrosporous nannandrous.*—Oogonia intercalary or terminal in position occurring singly or in pairs, also in threes (Figs. 2 and 3), pronouncedly oval or oval-ellipsoid in shape. Oospore chocolate in colour, oval, almost completely filling the oogonium. Oospore wall very thick bearing obliquely arranged or straight hyaline striations, 10–15 in number which often anastomose (Fig. 2). Basal cells flattened 45–50 $\mu$ broad (Fig. 4). Vegetative cells swollen with starch. Androsporangia in rows of 3–6 (Fig. 1 *a*). Nannandria 2–6 on the basal cells and the walls of the oogonium. Antheridia always internal. Oospores germinating to produce 4 zoospores oval in shape, 10 $\mu$ broad, 18 $\mu$ long (Fig. 7).

This alga very much resembles *Oe. Wolleanum* Wittrock in dimensions of cells and oospores but differs from that form in having an internal antheridium and in having no pore in the wall of the oogonium, the opening taking place by a superior lid, and its peculiar striations.

| | | | |
|---|---|---|---|
| Diam. of veget. cells female plants | .. 28–32 $\mu$ broad, | 4–5 times as long. |
| ,, ,, ,, male ,, | .. 21–25 $\mu$ ,, | 2–3 times long. |
| ,, oogonia | .. 75–80 $\mu$ ,, | 85–90 $\mu$ long. |
| ,, oospores | .. 75 $\mu$ ,, | 85 $\mu$ long. |
| ,, androsporangia | .. 23 $\mu$ ,, | 20–27 $\mu$ long. |
| ,, nannandria | ... 18 $\mu$ ,, | 72 $\mu$ long. |

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*Habit.*—This alga was found epiphytic on submerged radial stems of waterplants, in Shahniwala Tank at Dasuya, during the second week of March 1930.

2. *Oedogonium multisporum.* Wood.—Tiffany, 1930, p. 131.

*Diœcious nannandrous*, oogonia 1-3, sub-ovoid or subglobose, pores superior, oospore globose nearly filling oogonia (Fig. 7 *a*), spore-walls smooth, dwarf male a little curved near or on the oogonium, antheridium exterior 1-4 (Fig. 8).

*Distribution.*—U.S.A., England.

Vegetative cell of the female plant  .. 14-18 $\mu$ broad,  2-3 times long.
Oogonia                 .. 32-40 $\mu$  ,,  28-34 $\mu$ long.
Oospore                 ..  32 $\mu$  ,,  28 $\mu$ long.
Nannandria              .. 14-18 $\mu$  ,,  2-3 times as long.

*Habit.*—Reported by Mr. Prem Lal from ponds in Lahore and Gujranwala in the first week of December 1933.

B. SECTION *Dioica macrandria.*—

3. *Oedogonium capilliforme* Kutz. var. nov. *nanum.*—*op. cit.*, Heering, *Susswasser flora*, Heft. 6.

Diœcious macrandrous, oogonia single or in pairs. Ovoid to sub-ovoid or even slightly ellipsoid in shape with a superior pore. Oospore globose or ovoid globose completely filling the oogonium (Fig. 9). Spore walls smooth. Antheridia 2-4 celled usually alternating with the vegetative cells, two sperms in each, division horizontal (Fig. 10). This differs from the type in the smaller dimensions of its vegetative cells, oogonia, oospores and antheridia.

*Distribution.*—So far this species has only been reported from Europe and United States of America.

Diam. of female veget. cells  .. 18-20 $\mu$      2-3 times as long.
  ,,    male  ,,    ,,    .. 10-12 $\mu$    2-4    ,,
  ,,    oogonia          .. 30-36 $\mu$ broad, 32-40 $\mu$ long.
  ,,    oospores         .. 34-36 $\mu$  ,,  32-40 $\mu$ long.
  ,,    antheridia        ..  10 $\mu$  ,,   5 $\mu$  ,,

*Habit.*—Found growing epiphytically on blades of rushes in a pond in village Shahpur, Tehsil Dasuya, District Hoshiarpur, in the middle of April 1936.

4. *Oedogonium cardiacum.* Wittrock.—*op. cit.*, Heering, *Susswasser flora*, Heft. 6.

Diœcious macrandrous, oogonia single ovoid elliptical in shape. Broadened and bulging out laterally. Pore wide, situated a little above the middle.

Oospore rounded, fire-red in colour not completely filling the oogonium (Fig. 11). Oospore membrane smooth. Male filaments a little more slender than the female filaments. Antheridium 2-3 celled (Fig. 12). Sperms not seen.

*Distribution.*—So far this species has been only reported from Continental Europe and United States of America.

Diam. of veget. cells of female plants    26-28 μ broad, 3-5 times as long.

| ,, | ,, | ,, | male | ,, | 22-25 μ | ,, | 3-5 | ,, |
|----|----|----|------|----|---------|----|-----|----|
| ,, | oogonia | | | .. | 54-60 μ | ,, | 60-70 μ long. | |
| ,, | oospores | | | .. | 50 μ | ,, | | |
| 2 | antheridial cells | | | .. | 8- 9 μ long, | 23 μ broad. | | |

*Habit.*—Epiphytic on blades of grass, and decaying shoots of trees, mixed with *Oedogonium urbicum*, *Anabænothrix cylindrica* and *Zygnema chalybdospermum* in a pond at village Jhingran, District Hoshiarpur, in the last week of March 1930.

5. *Oedogonium Frankilianum.* Wittrock. sec. Hirn., var. *Polyspora*, var. nov.

Diœcious macrandrous, oogonia single or in groups of 2-3. Globose or ellipsoid globose, opening by a superior pore. Oospores rounded, chocolate in colour when mature, sometimes completely filling the oogonium, sometimes partly (Figs. 13, 14, 15). Oospore wall smooth. Suffultory cell wider than the ordinary cells. Male plant slightly narrower than the female plants. Antheridia 3-4 celled separated by a single vegetative cell. Sperms two, division horizontal. Vegetative cells distinctly capitellate.

This differs from the type in : (*a*) Bigger dimensions of vegetative cells and oospores, (*b*) having more than one oogonium in a series, (*c*) oospores often not completely filling the oogonium. Hence the new variety has been established.

*Distribution.*—So far this alga has only been reported from Roumania.

Diam. of veget. cells of female plants    9-18 μ broad,    4-6 times as long.

| ,, | ,, | ,, | male | ,, | 7-12 μ | ,, | 4-6 | ,, |
|----|----|----|------|----|--------|----|-----|----|
| ,, | oogonia | | | .. | 26-36 μ | ,, | 38-40 μ long. | |
| ,, | oospores | | | .. | 24-35 μ | ,, | | |
| ,, | antheridial cells | | | .. | 10 μ | ,, | 9 μ | ,, |

*Habit.*—This is rather a rare form, and was found growing epiphytically on the stems of a submerged water plant, along with *Eudorina elegans* near Beas, during the last week of April 1930.

6. *Oedogonium inerme* Hirn. var. *Polyspora*. var. nov.—(Section Nicht genugend bekannte Aretn. Heering, *Susswasser flora*, Heft 6.).

Dioecious macrandrous (probably) oogonia 1–3, usually single or in pairs. More rarely in a row of three (Figs. 16, 17, 18). Pore in the middle. Oogonia transversely ellipsoid. Oospore chocolate in colour almost of the same shape as the oogonium which it completely fills. Oospore wall smooth. Vegetative cells not capitellate. Male plants not known.

This differs from the type in having oogonia in a series of two or three and the oospores completely filling the oogonia and in the smaller size of the vegetative cells, oogonia and oospores. Hence this new variety has been established.

*Distribution.*—So far this species has only been reported from France.

Diam. of veget. cells         ..  5– 9 $\mu$ broad,  4– 6 times as long.

 ,,      oogonia            ..   21 $\mu$  ,,         19 $\mu$ long.

 ,,      oospores           ..   19 $\mu$  ,,     16 17 $\mu$  ,,

*Habit.*—Found attached to decaying leaves of *Dalbergia sissoo*, in a brownish mass in a rain-water puddle near Hamira, during the second week of March 1930.

7. *Oedogonium lautumnarium.* Wittrock.—*op. cit.*, Heering, *Susswasser flora*, Heft 6.

Dioecious macrandrous. Oogonia always single, globose or slightly expanded in the upper portion. Opening by a superior pore. Oospores yellowish in colour, globose, with a thick opaque whitish smooth wall (Figs. 19, 20). Male plants as big as the female plants or slightly smaller. Antheridia 3-celled, each with 2 sperms, division horizontal (Fig. 21). Suffultory cells of the same diameter as the vegetative cells. It differs from the type in oospores not completely filling the oogonia.

*Distribution.*—This alga is so far only known from Finland and Sweden.

Diam. of veget. cells female plants.. 18-20 $\mu$ broad,  3–6 times as long.

 ,,       ,,    ,,   male   ,,  .. 14-16 $\mu$  ,,      3–6       ,,

 ,,      oogonia          .. 40-42 $\mu$  ,,     42–48 $\mu$ long.

 ,,      oospores          ..   36 $\mu$  ,,

 ,,      antheridial cells     .. 13-14 $\mu$  ,,      5-8 $\mu$   ,,

*Habit.*—Epiphytic on water-plants, in a pond near Hamira, along with *Spirogyra dubia*, *Oedogonium lautumnarium* and *Sirogonium sticticum*, during the middle of April 1930. It is rather a rare alga.

8. *Oedogonium Pisanum.* Wittrock.—*op. cit.*, Heering, *Susswasser flora*, Heft 6.

Diœcious macrandrous. Oogonia single, both terminal and intercalary opening by a superior lid (Fig. 22). Oospore oblong ellipsoid, completely

filling the oogonium, oospore membrane smooth. Antheridia 2-celled, sperms 2, division horizontal (Figs. 23, 24). Suffultory cells not broader than the vegetative cells.

*Distribution.*—So far the species has only been reported from Europe and United States of America.

| | | | | |
|---|---|---|---|---|
| Diam. of veget. cells | .. | 5-9 $\mu$ broad, | 18-36 $\mu$ long. |
| ,,    oogonia | .. | 16 $\mu$ ,, | 36 $\mu$ ,, |
| ,,    oospores | .. | 14-15 $\mu$ ,, | 24-30 $\mu$ ,, |
| ,,    antheridia | .. | 4-5 $\mu$ ,, | 3-5 $\mu$ ,, |

*Habit.*—Epiphytic on decaying leaves of *Dalbergia sissoo* along with *Oedogonium Pisanum* and *Oe. Hirnii* in a puddle near Hamira, during the second week of April 1930. The filaments present a greyish appearance.

9. *Oedogonium rivulare* Hirn. var. nov. *nanum.*—*op. cit.*, Heering, *Susswasser flora*, Heft 6.

Diœcious macrandrous. Oogonia usually single, rarely in pairs. Pore superior, oogonia ellipsoid globose, oospore chocolate in colour, ovoid, not completely filling the oogonium, oospore wall smooth (Figs. 25, 26). The suffultory cells not swollen. Male filaments narrower than female filaments. Antheridia 5-7 celled but sometimes very numerous as many as 17 (Fig. 27).

This species differs from the type in its (1) usually single oogonia, (ii) oospores almost completely filling the oogonium, (iii) smaller size of oogonium (in *Oedogonium rivulare* Hirn. they are as much as 160 $\mu$ broad). So it may be taken as a new variety.

*Distribution.*—So far this species has only been reported from Germany.

| | | | | | |
|---|---|---|---|---|---|
| Diam. of veget. cells of female plant | | 36-47 $\mu$ broad, | 3-5 times as long. |
| ,,    ,,    ,,    male | ,, | 32-34 $\mu$ ,, | 3-5 ,, |
| ,,    oogonia | .. | 81 $\mu$ ,, | 90 $\mu$ long. |
| ,,    oospore | .. | 76 $\mu$ ,, | 80 $\mu$ ,, |
| ,,    antheridial cells | .. | 12 $\mu$ long, | 28 $\mu$ broad. |

*Habit.*—This alga was found free-floating in a blackish mass, along with *Cylindrocapsa* sp., in the famous tank at Dasuya, District Hoshiarpur, during the middle of October 1929.

10. *Oedogonium sociale.* Wittrock.—*op. cit.*, Heering, *Susswasser flora*, Heft 6.

Diœcious macrandrous, oogonia single, globose in shape, intercalary, oospore deep-yellow in colour, completely filling the oogonium (Fig. 28). Oospore membrane smooth, basal cells swollen. Antheridia 1-5 celled (Fig. 29).

This alga is very social in its growing habit, its individuals occurring in large numbers as epiphytes on water-plants.

*Distribution.*—This species is widely distributed in Europe and America.

| Diam. of veget. cells | .. | .. 9-15 $\mu$ broad, | 3-5 times as long. |
|---|---|---|---|
| ,,      oogonia | .. | .. 34-37 $\mu$  ,, | |
| ,,      oospores | .. | .. 26-30 $\mu$  ,, | |
| ,,      antheridial cells | .. | .. 12-14 $\mu$  ,, | 10 $\mu$ long. |

*Habit.*—This is one of the commonest and the most widely distributed species of *Oedogonium* and grows as an epiphyte on the submerged leaves and stems of the aquatic plants. Sometimes we can get pure growths of this alga, showing a harvest of bright yellow oospores, under the microscope. In some cases it is also found mixed with *Oedogonium urbicum*, and *Oe. cardiacum*. Collected from nearly all over the Eastern Punjab during the middle of March 1930.

11. *Oedogonium fonticola.* Al. Braun.—Pascher, 1914, p. 225; Tiffany, 1930, p. 163.

Diœcious macrandrous, oogonia 1-2, obovoid, or globose obovoid, ellipsoid or subglobose, oospore nearly filling the oogonium, spore-wall smooth. Male filaments very narrow (Figs. 30 and 31).

*Distribution.*—U.S.A., Australia, Europe.

| Vegetative cells of female plant | .. 16-18 $\mu$ broad, | 28-48 $\mu$ long. |
|---|---|---|
| ,,         ,,      male    ,, | .. 12-14 $\mu$    ,, | 2-3 times as long. |
| Oogonia | .. 30-40 $\mu$    ,, | 32-36 $\mu$ long. |
| Oospore | .. 32 $\mu$    ,, | 32 $\mu$   ,, |
| Antheridial cells | .. 8-10 $\mu$    ,, | |

*Habit.*—Found free-floating in a pond at Lahore by Mr. Prem Lal, during the first week of December 1933.

12. *Oedogonium glabrum* sp. nov.

Diœcious macrandrous, oogonia always single, globose, pore not seen, though very probably it opens by a pore. Oospore globose, completely filling the oogonium. Oospore wall smooth. Cells of the female filaments very short and rounded, with a thick wall and a conspicuous pyrenoid in the middle, vegetative cells very peculiar (Fig. 33). Male filaments have rows of 5-7 antheridia, separated by long cylindrical cells (Fig. 34). Basal cells elongate (Fig. 32). This species comes nearest *Oedogonium suecicum*. Wittrock. sec. Hirn. from which it differs in the oospore membrane being smooth and not spinous, and vegetative cells being much broader and smaller in length and its sex organs being slightly bigger.

Diam. of veget. cells of female plants 26-28 $\mu$ broad, 28-30 $\mu$ long.

,,       ,,       ,, male     ,,    15-20 $\mu$    ,,    28-30 $\mu$ long.

,,      oogonia            .. 36-45 $\mu$    ,,

,,      oospores          .. 32-40 $\mu$    ,,

,,      antheridial cells    .. 14-16 $\mu$    ,,    6-8 $\mu$   ,,

*Habit.*—Free-floating in a pond. Collected at V. Jhingran, District Hoshiarpur, in the middle of March 1930.

13. *Oedogonium rufescens.* Wittrock. var. *Lundellii.*—Tiffany, 1930, p. 66 ; Pascher, p. 192.

Diœcious macrandrous, oogonia 1–3, obovoid or depressed obovoid, globose. Pore median, oospore globose or depressed globose, filling the oogonium.

*Distribution.*—Southern Tibet.

Vegetative cells of the female filaments.. 8-10 $\mu$ broad, 30-40 $\mu$ long.

Oogonia                   .. 22-24 $\mu$    ,,    20-26 $\mu$    ,,

Oospore                   .. 20-22 $\mu$    ,,    17-20 $\mu$   ,,

*Habit.*—This alga was found by Mr. Prem Lal, free-floating in a pond at Lahore, during the third week of November 1933, and also by the author at Saharanpur, during, the first week of December 1935.

14. *Oedogonium calcareum.* Cleve.—Pascher, 1914, p. 192 ; Tiffany, 1931, p. 67.

Diœcious macrandrous, oogonia one or rarely two, depressed globose, oospore depressed, globose filling the oogonium, oospore wall smooth (Fig. 35).

Grows epiphytically on *Chara*, and is often encrusted with lime (Fig. 36).

*Distribution.*—England, Denmark and Sweden.

Vegetative cells of the female plant.. 12-16 $\mu$ broad, 2-3 times as long.

Oogonia                   .. 32-44 $\mu$    ,,    32-36 $\mu$ long.

Oospores                 .. 30-40 $\mu$    ,,    32 $\mu$    ,,

*Habit.*—This alga was first reported by Mr. Prem Lal from an aquarium at Lahore, growing epiphytically on *Chara*, during the first week of December 1933, and also by the author at Roorkee, in a pond growing on *Chara*.

C.    SECTION *Monoica Macrandria.*—

15. *Oedogonium gracillimum.* Wittrock and Lund.—*op. cit.*, Heering. *Susswasser flora,* Heft 6.

Monœcious macrandrous, oogonia single, both terminal and intercalary, opening by a superior lid. Oogonia oblong ellipsoid, oospores of the same shape as oogonia and completely filling them. Oospore walls smooth,

antheridia 2-3 celled, each with two sperms, division horizontal. Suffultory cells not swollen (Figs. 37 and 38).

Diam. of veget. cells .. .. 9 μ broad, 36-42 μ long.
,, oogonia .. .. 14-17 μ ,, 24-36 μ ,,
,, oospores .. .. 14-16 μ ,, 23-30 μ ,,
,, antheridial cells .. 4- 5 μ ,, 7-8 μ ,,

*Habit.*—Rather a rare form, found epiphytic on decaying leaves along with *Oedogonium Pisanum* and *Oe. Hirnii* at Hamira, during the middle of April 1930.

16. *Oedogonium Hirnii.* Gutwinski.—*sp. cit.,* Heering, *Susswasser flora,* Heft 6.

Monœcious macrandrous, oogonia usually single, occasionally in pairs, globose. Opening with a big superior pore. Oospore globose, not completely filling the oogonium, yellowish in colour, oospore walls smooth. Antheridia 2-celled, each with two sperms, division horizontal (Figs. 39 and 40).

*Distribution.*—So far this species has only been reported from Europe.

Diam. of veget. cells .. .. 20-22 μ broad, 3-6 times as long.
,, oogonia .. .. 32-36 μ ,, 36-39 μ long.
,, oospores .. .. 28-32 μ broad.
,, antheridia .. .. 18 μ ,, 9 μ ,,

*Habit.*—Grows as an epiphyte on decaying leaves in puddles along with *Oedogonium gracillimum* and *Oe. Pisanum.* Found near Hamira, during the middle of April 1930.

17. *Oedogonium oblongellum.* Kirchner.—*op. cit.,* Heering, *Susswasser flora,* Heft 6.

Monœcious macrandrous, oogonia single, elliptical, operculate, division at the upper extremity of the oogonium. Oospores ellipsoid, globose, completely filling the oogonium. Oospore membrane smooth. Antheridia 2-celled (Fig. 41), each with two sperms. Vegetative cells not capitellate. Suffultory cell not swollen.

Diam. of veget. cells .. .. 9-12 μ broad, 3-4 times as long.
,, oogonia .. .. 25-28 μ ,, 40-46 μ long.
,, oospores .. .. 27 μ ,, 31 μ ,,
,, antheridium cells .. .. 9-10 μ long.

*Habit.*—Found epiphytic on grass blades in a pond near village Shahpur, District Hoshiarpur, during the middle of April 1930. This is a fairly common form.

18. *Oedogonium urbicum.* Wittrock.—*op. cit.*, Heering, *Susswasser flora*, Heft 6.

Monœcious macrandrous, oogonia single, ellipsoid globose, pore superior, oospores rounded, not completely filling the oogonium, of dense black colour oospore walls smooth (Fig. 42).

Diam. of veget. cells    .. 18-20 μ broad,   2-3 times as long.
 ,,   oogonia     .. 41-46 μ  ,,   50-52 μ long.
 ,,   oospore     .. 40-42 μ  ,,
 ,,   antheridia    ..  10 μ  ,,    5 μ  ,,

*Habit.*—Epiphytic on submerged plants and decaying shoots of trees, in a pond near village Jhingran, District Hoshiarpur, along with *Oedogonium inerme* and *Vaucheria sessilis.* A very common alga during the middle of March.

### *Genus Bulbochæte* Agardh.

1. *Bulbochæte* sp.—This was found associated with *Stigeoclonium nanum.* Cells are 16-18 μ broad, 18-24 μ long. Each cell bears the characteristic long spines with a bulbous base (Fig. 43). This is a branched form. The material was indeterminable due to the absence of sex organs.

*Habit.*—Found in a pond near Hamira, District Jullunder, epiphytic on grass stems along with *Stigeoclonium nanum, Coleochæte soluta* and *C. scutata*, in the month of March 1930.

2. *Bulbochæte* sp.—This was found epiphytic on *Chætomorpha.* The alga is in the form of 10-20 celled unbranched filaments. The terminal cells bearing a long trichome with a bulbous base (Fig. 44). Cells are 8-9 μ in diameter, 2-3 times as long. This is probably the juvenile stage of some *Bulbochæte* species.

*Habit.*—Found epiphytic on a shoot of *Hydrilla* along with *Aphanochæte repens* and *Chamæsiphon filamentosa* in the tanks in Shalamar Gardens, Lahore, in November 1929.

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## EXPLANATION OF FIGURES.

All figures are magnified 715 times.

### PLATE VI.

FIGS. 1–7.—*Oedogonium striatum* sp. nov. Randhawa.
  FIG. 1.—A filament showing androsporangia.
  FIG. 2.—A female filament showing a pair of ripe oogonia with oospores.
  FIG. 3.—A female filament with a nannandrium germinating on the basal cell.
  FIG. 4.—The attachment cell. .
  FIG. 5.—A female filament showing two dwarf males germinating on the basal cell.
  FIG. 6.—A dwarf-male.
  FIG. 7.—A germinating oospore with four zoospores inside the membrane.

FIG. 8.—*Oedogonium multisporum* (Wood).
  A female filament with oospores, and nannandrium germinating on an oogonium.

FIGS. 9–10.—*Oedogonium capilliforme.* Kutz.
  FIG. 9.—A female filament.
  FIG. 10.—A male filament.

FIGS. 11–12.—*Oedogonium cardiacum.* Wittrock.
  FIG. 11.—A female filament showing a ripe oospore.
  FIG. 12.—A male filament showing antheridia.

### PLATE VII.

FIGS. 13–15.—*Oedogonium Frankilianum.* Wittrock. var. *Polyspora* var. nov.
  FIG. 13.—A female filament showing a ripe oospore.
  FIG. 14.—A male filament showing antheridia.
  FIG. 15.—A male filament showing three oogonia in a series.

FIGS. 16–18.—*Oedogonium inerme.* var. *Polyspora* var. nov.
  FIGS. 16–18.—Filaments showing oogonia with ripe oospores.

FIGS. 19–21.—*Oedogonium lautumnarium.* Wittrock.
  FIGS. 19–20.—Female filaments showing oogonia.
  FIG. 21.—Male filament showing antheridia.

FIGS. 22–24.—*Oedogonium Pisanum.* Wittrock.
  FIGS. 22–23.—Male filaments showing antheridia.
  FIG. 24.—A female filament showing oogonia.

FIGS. 25–27.—*Oedogonium rivulare.* Hirn.
  FIG. 25.—A filament showing an oogonium with an oospore.
  FIG. 26.—A filament showing two oogonia.
  FIG. 27.—A male filament showing antheridia.

FIGS. 28–29.—*Oedogonium sociale.* Wittrock.
  FIG. 28.—A male filament showing empty antheridia.
  FIG. 29.—A female filament showing oogonia with ripe oospores.

### PLATE VIII.

FIGS. 30–31.—*Oedogonium fonticola.* Al. Braun.
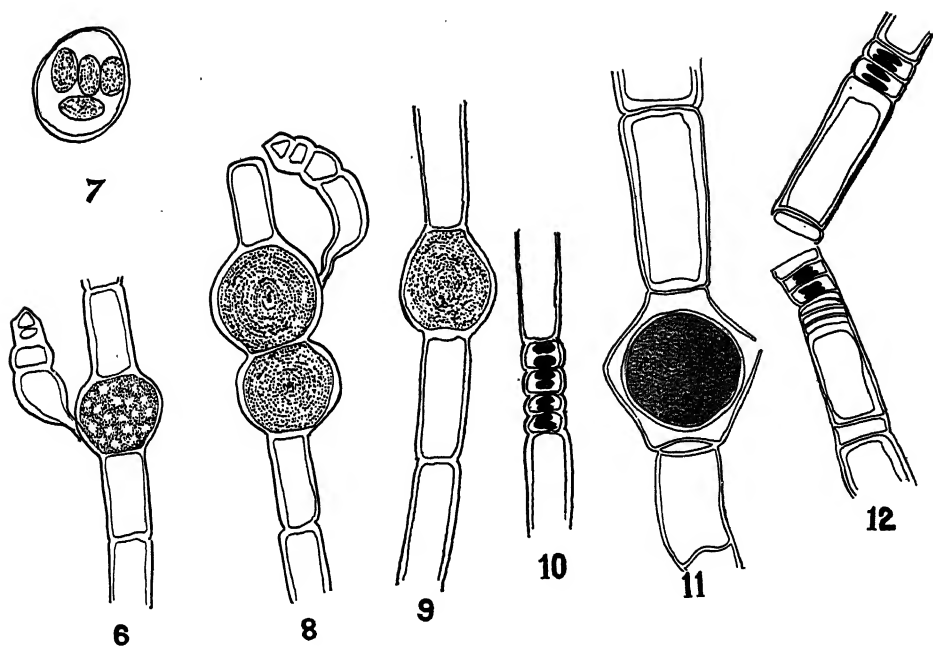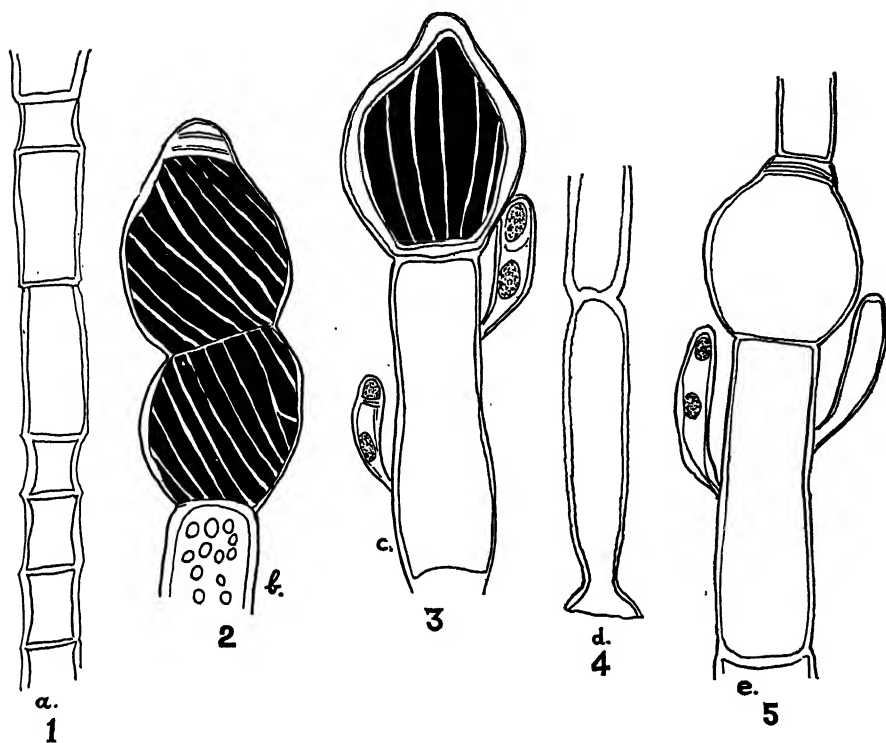  FIG. 30.—A female filament showing oogonia and an oospore.
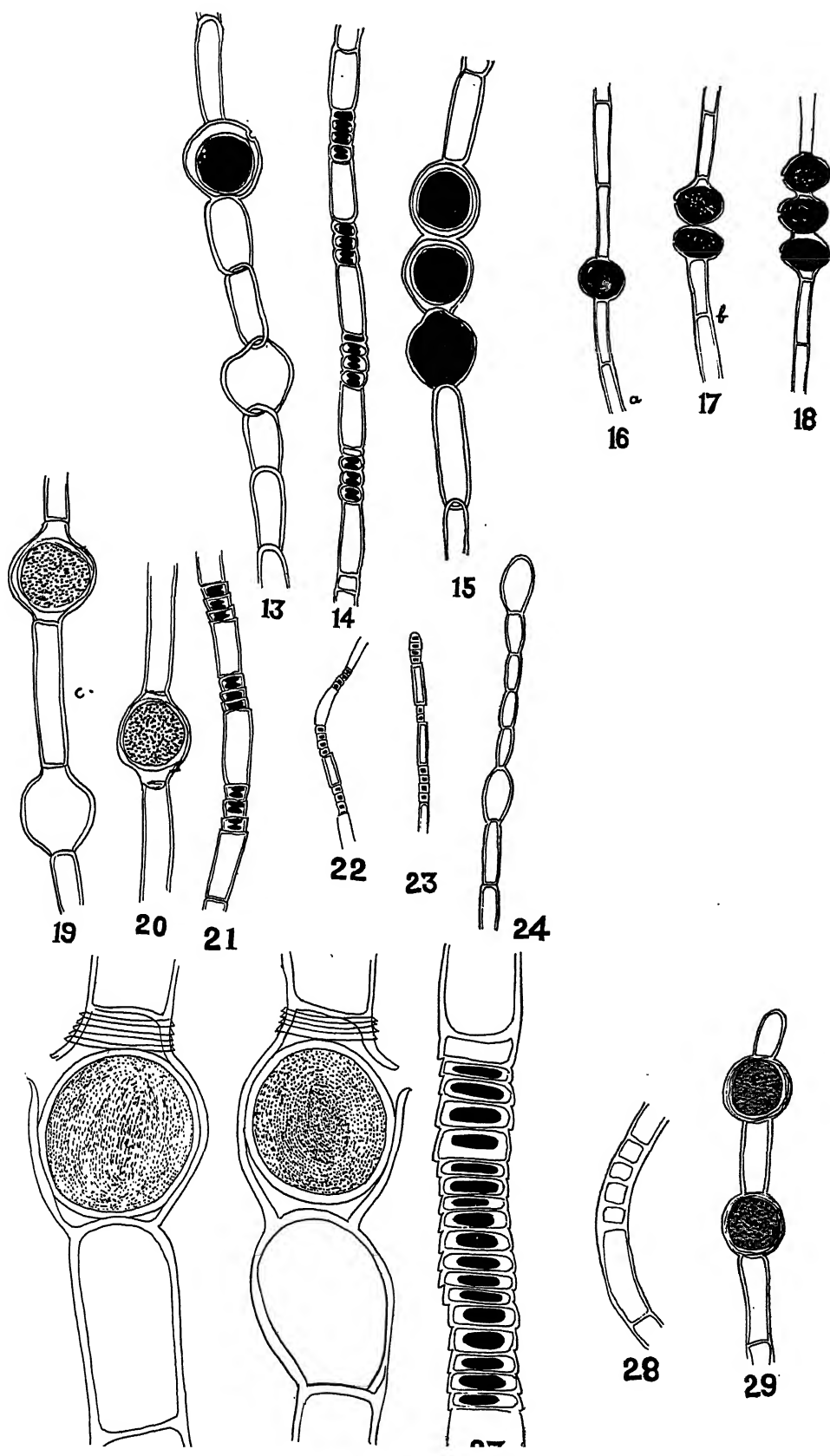  FIG. 31.—A male filament showing antheridia.

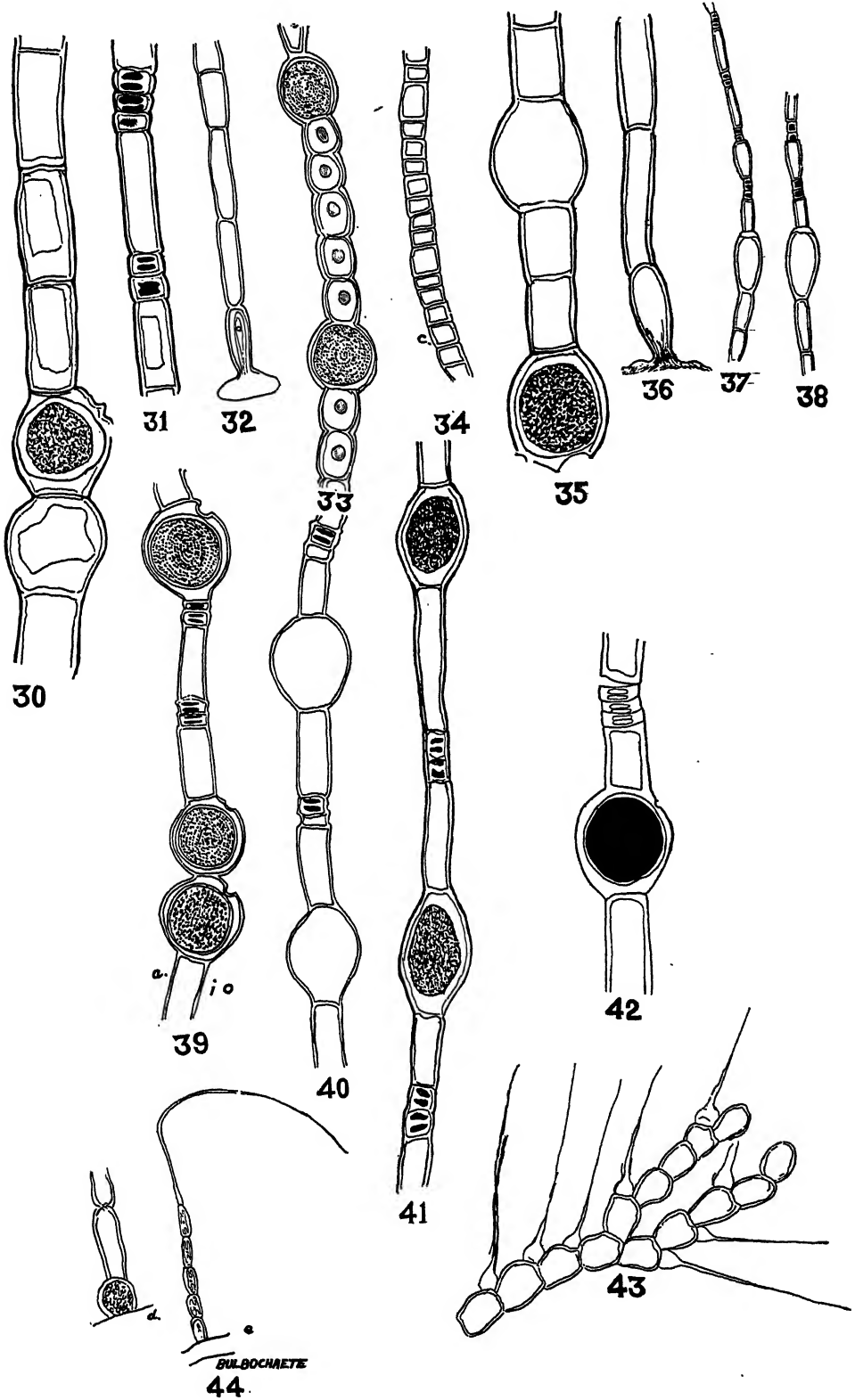FIGS. 32–34.—*Oedogonium glabrum.* sp. nov. Randhawa.
  FIG. 32.—A filament showing the basal cell.
  FIG. 33.—A female filament with two oogonia containing ripe oospores.
  FIG. 34.—A male filament.

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Figs. 35–36.—*Oedogonium calcareum* (Cleve)..
  Fig. 35.—A female filament showing an oogonium with a ripe oospore.
  Fig. 36.—Basal cell.
Figs. 37–38.—*Oedogonium gracillimum.* Wittrock and Lund.
  Figs. 37, 38.—Filaments showing antheridia and oogonia.
Figs. 39–40.—*Oedogonium Hirnii.* Gutwinski.
  Fig. 39.—A filament showing ripe oospores and antheridia.
  Fig. 40.—A filament showing immature oogonia and antheridia.
Fig. 41.—*Oedogonium oblongellum* (Wittrock).
  A filament showing oogonia and antheridia.
Fig. 42.—*Oedogonium urbicum.* Wittrock.
  A filament showing an oogonium with a ripe oospore and antheridia.
Fig. 43.—*Bulbochæte sp. x.*
  A branched filament.
Fig. 44.—*Bulbochæte sp. y.*
  Two unbranched filaments.

# A NEMATODE DISEASE OF RICE IN THE CENTRAL PROVINCES.

By Jehangir Fardunji Dastur, M.Sc.

*Mycologist to Government, C.P., Nagpur.*

The rice plant in the Central Provinces is usually free from serious diseases. The disease which causes at times much damage is the one resembling "Straight Head Disease". It is usually found in certain fields; varieties like Gurmatia and Bhata Gurmatia being particularly susceptible. In the early stages, the growth of the plant is checked and there is at the same time a large increase in the development of coarse roots which are sparingly branched and which have very few root hairs. The affected plants produce poor heads which may be partially sterile. The trouble is due to unfavourable soil conditions which can be remedied by letting out water from the affected fields as soon as the arrest in normal growth of plants is noticed and by allowing the field to get dry till the soil begins to crack when the water can be again turned on, but sparingly.

There are some other diseases of minor importance, such as those caused by *Piricularia oryzæ* Cav., *Entyloma oryzæ* Syd. and *Helminthosporium* spp.

Besides these diseases, there are two others which are of sporadic occurrence and which have been under investigation for the last few years. In one case, there is the dying of the outer leaves and of tillers, in the other case there is the development of "light" ears and spotting of grains. These diseases are at times very destructive; some varieties are much more susceptible than others; for example, in 1935, at Waraseoni (Balaghat District) early varieties of rice, such as E. B. 17, Pisso and Luchai 21, were very badly affected; their outer leaves and tillers died in large numbers; in 1934 in Chhatisgarh District, the yield of early varieties of rice, such as Ludka, was considerably reduced, as they produced chiefly "light" ears; there was also the dying of outer leaves and of tillers; but in 1935 in Chhatisgarh District the crop was normal.

It is probable that these two diseases may be caused by the same organism.

*Symptoms.*—Certain varieties of rice, especially early varieties such as Ludka, E.B. 17 and Pisso, show a diseased condition when the plants are

about two to three months old. The first symptom of the disease is the slow dying of the outer leaves from tip downwards. The tip of the outermost leaf at first turns brown and dry; the browning and drying slowly extends downwards along the margin, and later the whole leaf is involved; The margins more or less curl inwards; the dry leaf stands erect; it does not, at first, show any marked lesions or signs of rot. The inner leaves also soon show similar symptoms; the tillers are also affected in the same way and they die before they put forth a vigorous growth or many leaves. The plant is ultimately so attenuated that it has only a few inner leaves and a thin stem bearing a poor head, most of the leaves being dry, and most of the tillers being dead or dying.

When such a plant, having only a few green leaves, is uprooted, the roots are found to be healthy and normal. The lower internodes of the stem are white and do not show any signs of disease except a few stains, brown or reddish brown, on the short lower internodes. When the outer leaves of the parent plant are removed the buds in the leaf axils are distinctly black coloured, wholly or partially, and not white as the healthy buds; when the leaves of the dead or dying tiller are carefully removed, and the growing point is exposed, it is found to be black. A microscopic examination of sections of the blackened growing points of dying tillers, of the partially black buds in the axils of the outer dying leaves and of the stained lower internodes does not show the presence of any organism in their tissues; these tissues are discoloured deep brown or black, but they do not show the presence of any hyphæ or bacteria; these buds, growing points and internodes remain sterile in a majority of cases, when after sterilizing them in a solution of corrosive sublimate and washing them in sterilized water they are transferred to culture media tubes. Leaf-sheaths of the dead leaves of a diseased plant in a field in which water has been allowed to stand for a long time have at times within their tissues and on their surfaces, small black minute sclerotia measuring $47-129 \times 54-150\,\mu$, but these sclerotia are not found on the leaf-blades or in their tissues; they are confined only to those parts which are usually under water. In some cases, the leaf-sheaths of dying leaves, which are under water, show distinct lesions, brownish in colour and elliptical in shape; these lesions may extend to the inner side of the leaf-sheath; on the parts of the culm which is in contact with these lesions may be found at times a greyish felt of mycelium; the part of the stem to which the mycelium is attached shows brownish or blackish lesions; in sections through these lesions on the stem no mycelium inside the tissues is found though the epidermical tissues are discoloured; the felt of the mycelium is entirely superficial.

Diseased specimens of rice, collected last year from Waraseoni (Balaghat District) at first did not show the presence of any sclerotia either on the leaves and stems or inside their tissues; but when these plants were kept in water for a few days, large black sclerotia, about 0·25 mm. in diameter were found in large numbers. They were also present inside the hollow stems; but were confined only to the lower parts of the plants.

When a plant in flower has its inflorescence still enclosed within its enveloping bract, it is hardly possible to say whether the panicle, when it emerges from its boot, will develop into a normal ear or a "light" ear, as the enveloping sheath is usually green and does not usually show lesions on its outside; but when the panicle emerges from the boot the extent to which the ear is diseased can be readily seen even from a distance, as the diseased spikelets stand out very conspicuously amongst the healthy ones.

In normal years, the number of spikelets attacked in a panicle is not great and often it is negligible; but still the diseased spikelets can be readily distinguished from amongst the numerous healthy spikelets of the inflorescence. The flower in a diseased spikelet is either sterile or completely aborted; in the former case the inner glumes, the palea and lemma, are of normal size and shape, but are white coloured and therefore can be readily distinguished from the green glumes of healthy flowers; these diseased flowers have anthers and pollen grains of normal size and shape, but the anthers remain within the white glumes, even though these may have spread apart; the lodicules and the ovary are rudimentary or wilted, but the two stigmas look normal. In those spikelets in which the glumes are distorted and empty, the flower is absent; the palea is papery or membranous, white in colour and crescent shaped; it may be embedded within the lemma, which is also sickle shaped, white in colour and thinner than the lemma of the healthy flower. Both the glumes may be of the same length as those of the healthy flower or may be smaller, but they are much narrower in width than the normal glumes. In some cases, the apical part of the lemma is hook shaped and bends over the palea which is more or less rudimentary. The external glumes may be normal, or very much enlarged, as long as the inner glumes, or may be completely wanting.

When the ear is fully matured and dry its " light " grains having normal sized glumes, which were originally white coloured, slightly turn light brown and so cannot be then easily differentiated from the straw coloured glumes of a ripe normal fruit.

Neither the peduncle, nor the rachis, nor the pedicel shows any rot or decay, though at times the pedicel of an aborted flower may be discoloured dirty brown.

In some cases, the inflorescence does not wholly emerge from the boot-leaf ; the basal part remains enclosed within the enveloping sheath ; the flowers enclosed within the lower part of the unopened sheath are steri'e ; their inner glumes are usually of normal shape and size but their colour is wholly white ; the boot-leaf may show distinct brownish stains which are not very sharply demarcated.    At first the enclosed portion of the inflorescence shows no signs of rot ; but at a later stage, especially under wet conditions, it shows a distinct wet rot ; the originally white glumes are discoloured brown or black due to the infection of saprophytic organisms like bacteria, *Cladosporium* sp., *Alternaria* sp., *Fusarium* sp., *Phoma* sp., etc.  The peduncle, rachis and pedicel do not show any signs of wet rot though they may be discoloured.

When a newly opened inflorescence is carefully examined, it will be found that many of the green glumes of its normal healthy flowers have one or more very minute black circular spots or specks which can easily pass unnoticed ; in some cases, the spots are bigger and elliptical in shape ; these elongated spots have a dark brown or blackish border with a light brown or whitish centre.   The spots do not enlarge ; they retain their size and shape even after the flowers have set, and mature fruits are formed ; but in the case of the elliptical spots, the central portion becomes whiter and thinner ; and it often ruptures, on account of the death of the white central tissues, exposing the healthy kernel underneath.   The tiny specks are usually confined to the upper surface of the glumes.

The development of sterile or aborted flowers is chiefly confined to early varieties of rice, like Ludka ; late varieties, like Gurmatia, are not usually susceptible to this disease ; however, occasionally a few scattered sterile flowers or " light " grains may be found in a well developed ear.   But the ears of almost all varieties of rice, late or early, have a number of grains with spotted glumes.

In 1934, when the development of the " light " ears assumed an epidemic form in Chhatisgarh District, certain varieties were more affected than others ; Ludka was the most affected, Surmatia was much less affected, and Gurmatia and Chinoor were very little affected.   Practically, every field, where Ludka was grown, was diseased and every plant produced " light " ears.   A Ludka field in ear could be easily distinguished from fields of other varieties ; the large number of sterile flowers with their white glumes gave the panicle a distinctive appearance.   The apical spikelets had, in most cases, aborted flowers which had shed before the ear was ripe and so the tips of the pedicels were exposed.  .The panicles stood erect and did not turn down as do the healthy ones ; this was due to the development of " light " apical spikelets.

*Cause of the disease.*—When the ear is mature, the white aborted inner glumes of a spikelet or its pedicel are often covered with minute black sclerotia which are easily visible with the aid of a hand lens. They are globular or globoid and measure $47 \cdot 0$–$129 \times 54 \cdot 0$–$150 \mu$. When the aborted glumes or their pedicels are transferred, after sterilizing them with corrosive sublimate and washing them in sterilized water to culture media tubes, pure cultures of a *Rhizoctonia* are obtained, even in those cases in which sclerotia are not observed on the glumes and pedicels. In sections through the tiny spots on the glumes of healthy flower and fruits, only the epidermal cells and the adjacent cells are seen to be slightly discoloured brown. No hyphæ or bacteria have been found in these discoloured tissues. The white central part of the elongated and elliptical spots on the glumes of a ripe grain, has at times on its upper surface minute black sclerotia, similar to those found on rotting leaf-sheaths and aborted glumes ; but generally no organism has been found in these spotted tissues, especially when the grain is immature. In no case has the lesion been found to extend from the glumes to the enclosed kernel. The viability of the seed is not in any way affected by the spotting of the glumes. From the " light " grains, when incubated in culture media tubes, *Rhizoctonia* sp., *Helminthosporium* spp., *Acrothecium* sp., *Phoma* sp., *Nigrospora* sp. and bacteria were isolated from time to time. When the inner glumes, both of the mature healthy grain and of the " light " grain, are examined under a microscope conidia of *Helminthosporium* spp., *Acrothecium* sp., and *Nigrospora* sp., are found on the outer surface of the glumes ; conidia of *Nigrospora* sp. are particularly found in large numbers.

Rice seedlings at the time of transplantation were inoculated with these fungi and bacteria isolated from diseased plants but except the inoculations with the *Rhizoctonia*, bearing minute sclerotia, the inoculations were always unsuccessful. When the seedlings were inoculated with this *Rhizoctonia*, in a few cases, the plants showed some ill-effects of the inoculation. Their growth was at first rather arrested, compared with that of the control plants, and of those inoculated with other fungi ; but there was no dying of the outer leaves as found in the fields ; and at a later stage there was no difference between the inoculated and control plants ; the inoculated plants bore healthy normal ears as did the control plants. When an open inflorescence was inoculated with these fungi, the flowers, which had the inoculum on them did not set ; their inner glumes were discoloured black or brown ; the typical symptoms found in the naturally diseased flowers were not reproduced, the glumes were neither distorted nor were they white in colour. When the sheath covering the unopened inflorescence was inoculated with these organisms, the inoculations were wholly unsuccessful, except that in a few cases

the enveloping sheaths developed small lesions where the inoculum was placed ; the lesions did not grow further. These inoculated boot-leaves and those which served as controls were kept enclosed in glass or celluloid chimneys, the ends being plugged with wet cotton wool ; the panicle emerging from these boots often had typical sterile flowers with white inner glumes and spikelets with the typical white aborted glumes, similar to those found in naturally diseased ears ; but all attempts to re-isolate the fungus used for the inoculations from these empty grains and aborted glumes gave negative results. These inoculations were made repeatedly during the last three or four years but the results were always the same. Late last season (1935) the unopened ears inoculated with *Nigrospora* sp. and kept covered in glass chimneys for many days showed typical symptoms of a naturally diseased head ; the aborted glumes or the white glumes of sterile flowers did not show any trace of *Nigrospora* sp. The glumes and their discoloured pedicels in sections showed no presence of fungus hyphæ in their tissues. When, how-ever, the glumes of an empty grain were teased out in a drop of water on a slide and examined under the microscope a few live nematodes, belonging to the genus *Aphelenchoides*, were observed. When other empty grains were similarly examined the same type of nematodes were found. This led to the suspicion that the development of sterile grains may be due to the presence of these nematodes. " Control " ears which were similarly kept enclosed in chimneys had also developed empty grains ; and when these were examined, they were also found to contain the same kind of nema-todes. Herbarium specimens of Ludka and Surmatia collected in 1934 from Drug and Chandkhuri (Raipur District) were, therefore, re-examined last December, *i.e.*, more than a year after they were collected ; the white aborted glumes and the glumes of empty grains were teased out in a drop of water on a slide and in a majority of cases nematodes were observed ; each of them was coiled like a watch spring ; when kept in water for some time they uncoiled and straightened out ; in a few cases, they regained their motility, but in most cases they were dead. These nemas were identical to those found in empty grains last year. At the time this investigation was in progress, specimens of " light " ears were received from Labhandi (Raipur District), Drug and Waraseoni (Balaghat District) ; from sterile spikelets of these specimens also the identical nemas were found.

When the presence of nematodes in empty grains was noticed, the season had practically ended, the crops in fields were harvested, and so the disease could not be further studied under field conditions ; but there were a few potted plants in the experimental area. The main branches of these plants had ripe ears, but there were a few side shoots in bloom ; some of the

inflorescences had already, wholly or partially, burst through their boot-leaves and in others they were still enclosed within their sheaths. These heads opened and unopened, were kept under high humid conditions by covering them with glass or celluloid chimneys, the ends of which were plugged with moist cotton wool. Heads, which had opened completely before they were covered, bore a few empty grains but their glumes did not have the typical white colour of the naturally diseased spikelets. In these grains, nematodes were not observed. The heads, which, when they were covered, were either partially opened or wholly unopened, developed typical symptoms of disease ; all of them produced a number of empty grains and aborted glumes ; in some cases, the inflorescence opened only partially, the basal part remaining within the enveloping sheath. These lower parts of the head bore empty grains, the glumes were either white or had brown lesions on them. The sheath also in some cases showed brown stains, especially above and near the margins ; in no case was the main stalk diseased or discoloured. In all these heads, the typical nematode was found. In the spikelet with white glumes of a newly opened inflorescence the stigmas were shining and moist on account of the presence of nemas on them. In some cases, the spikelets had not at all developed, the flower buds had aborted and had turned brown. Nematodes were observed within these aborted flower buds as well (Plate IX, Fig. 10). Some late developed ears were inoculated with nematodes from diseased grains, and were kept covered with chimneys. These inoculated ears also gave typical diseased heads. Since the uninoculated covered heads, kept as " controls," gave the same results as the inoculated covered heads no conclusions can be drawn from these experiments, except that the nema is present on the upper parts of the plant and that it can cause no damage till the unopened or partially opened inflorescence is kept under high humid conditions.

These nematodes were not always found in large numbers in hte empty grains ; in a majority of cases they were about half a dozen in each grain ; individuals of both the sexes were at times found in a grain, but those of the male sex were much fewer in number, and were not found in all the diseased grains that were examined ; larvæ were found in some of the diseased specimens, but eggs were found very rarely.

The development of typical " light " ears from unopened inflorescences kept artificially under moist conditions at Nagpur, the presence of nemas in " light " spikelets and undeveloped flower buds, and the presence of the same nema in specimens of " light " ears received in 1935 from Drug, Labhandi, Chandkhuri and Waraseoni, confirm the suspicion that this nema is the cause of the disease, at least of the panicle, if not of the basal parts of

the plants as well; this suspicion is further confirmed by finding the same type of nema from herbarium specimens of diseased Ludka and Surmatia ears collected from Drug and Chandkhuri in 1934.

The soil used for our Nagpur pot experiments was evidently naturally infected with the nematode suspected to be the cause of "light" ears in rice, as is proved by the development of typical diseased inflorescences when kept artificially under high humid conditions; but still there was no dying of tillers or of outer leaves. This may be due to the fact that for the pot experiments Gurmatia variety was used, a variety which under field conditions at Drug and Waraseoni has not been known to be diseased. The dying of tillers and of outer leaves is generally found in certain varieties, like E.B. 17, Pisso, Luchai 21 and Ludka.

Whether the nematode found inside the glumes of sterile flowers is also the cause of the dying of the outer leaves and basal leaf buds and tillers of rice plants it is difficult to say definitely without further study. The absence of hyphæ and bacteria within the tissues of the blackened axillary leaf buds and of the growing points of dying tillers, and the failure of reproducing the disease from fungi and bacteria isolated from the lower parts of dead leaves and from diseased ears may be due to the disease not being of fungal or bacterial origin. Before the nematode was found in sterile flowers and grains a nematode belonging to the same genus was occasionally seen in the axils of leaves of fresh specimens received from Drug and Waraseoni, especially from those that were sent with the soil still adhering round the roots; but unfortunately at the time the presence of the nematode was not associated with the disease, and so it was not further studied. Dry herbarium specimens of diseased plants of E.B. 17 collected at Waraseoni in October 1935 were re-examined, a couple of months later; on removing the leaf-sheaths from the basal internodes which had lesions on them, adults, larvæ and eggs of nematodes were found in the axils of these leaves. Some of these nemas belonged to the genus *Aphelenchoides* and were similar to those found in diseased "light" ears. For these reasons it is suspected that the dying of the tillers and outer leaves may also be due to the same nematode found in the sterile or aborted parts of the head.

No direct evidence has been produced to establish a connection between the presence of the nematode and the spotting of the glumes of fertile flowers. The spotting of the glumes takes place when the inflorescence is still enclosed within the boot; no organism has been found in the tissues of the spotted part of these glumes; the cells are brown coloured or honey coloured; when a spotted glume of a flower which has just emerged from its boot or which is still enclosed within it is transferred to a culture medium tube, after

the glume has been sterilized with corrosive sublimate and washed in sterilized water, it has invariably remained sterile. The lesions on the glumes do not increase in size after the panicle has emerged from the boot and the grains have set; though the central dead parts of a lesion at times turns white and bursts as the fruit matures and ripens. It is therefore suggested that the spotting may be due to the activities of the nema on the outside of the glumes after the flower has well developed and the glumes have begun to get silicified and therefore it is not able to do any damage to the spikelet.

The incidence of "light" ears seems to be dependent on prevailing climatic conditions at the time the plant is heading. With the development of the plant the nemas are able to travel to its apical parts, where they may be active or inactive according as the climatic conditions are humid or dry. If there are frequent showers of rain when the plant is heading, as may happen in the case of early varieties like Ludka, and E.B.17, the nemas become active and attack tender flower buds and immature flowers having unsilicified glumes; therefore the inflorescence, when it opens out of the enveloping boot, has aborted flower buds or spikelets with sterile flowers and distorted empty glumes.

The epidemic of "light" ears in early varieties like Ludka, and Surmatia in Chhatisgarh District in 1934 was very probably due to the frequent showers of rain in the first half of October when the plants were heading.

Nagpur pot experiments have shown that Gurmatia, a late variety, is as susceptible as the early variety Ludka to the development of "light" ears, if its unopened inflorescences are kept under humid conditions; under natural field conditions late varieties, like Gurmatia, Luchai and Chinoor, are more or less immune to this disease. This immunity seems to be connected with their time of flowering. They start heading about the middle of October or later, by which time, the monsoon has practically ended; therefore the critical period when the unopened inflorescence is susceptible to being infested by the nema is normally not sufficiently humid and so these late varieties produce healthy ears, even though the nema may be present on the apical parts of the plants.

The nema disease causing "light" ears in these Provinces is different from "ufra" disease of rice well known in Bengal, and caused by *Anguillulina angusta* (Butler, 1913). Perhaps in very early stages of the disease, when the leaves die from tip downwards or when the boot-leaf enclosing the immature panicle may have brown stains, there may be some superficial resemblance between these two diseases. "Ufra" disease causes a stunting of the infected plant, and a rotting and shrinking of the peduncle near the node. It does not develop "light" ears with white glumes.

*Technique.*—A diseased grain was teased up in a drop of water on a slide and examined under a microscope; when nemas were present the pieces of glumes were carefully removed and the drop of water was allowed to evaporate till there was left on the slide just a smear of water; this process was accelerated by keeping the slide on a warm plate or in a dry place. The nemas were then covered with a drop of Amann's Lactophenol mounting medium (Lee, 1921) which was considerably diluted with water and which was faintly dyed with Cotton Blue. The excess of water from the diluted mounting medium was allowed to evaporate slowly and then a small drop of the uncoloured medium of normal strength was added; it was covered with a coverslip. Permanent preparations were made by ringing the coverslip with Canada Balsam after the water from the medium had completely evaporated.

The nemas in a drop of the diluted mounting medium soon lose their motility and come to rest, a majority of them in a straightened out position. At first there is considerable plasmolysis and so the nemas are very much shrunken and distorted in shape but as they absorb the coloured medium their turgor is restored and they regain their normal size and shape. The blue stain brings out clearly the various organs of the nemas. The spicules stain a much deeper blue than any other part and so stand out very conspicuously.

In this mounting medium the female nema comes to rest more or less straight, from the head to the tip of the tail; but the male nema in the resting position has always its tail curved upwards, almost in a semi-circle, but the remaining part of its body is straight (Figs. 1, 2, 5, 6, and Plate IX, Figs. 11–13).

*Morphology of Aphelenchoides sp.*—Body is tapering posteriorly and slightly anteriorly; cuticle is transversely finely striated; head is cap-like, offset by a constriction; the anterior part is slightly flattened; sides are convex; head has six longitudinal ridges; labial papillæ are present but indistinct; buccal cavity is usually as deep as the head. Stylet is in two parts; the posterior has two well-developed knobs at the base (Figs. 3 and 7). In the head region the wall of the alimentary canal has short thickenings. Oesophagus terminates in a muscular bulb, which is oval or ovoid or broadly elliptical in shape. Oesophagus merges into intestine without any line of demarcation. Oesophageal gland cells with a rounded or pointed posterior are present, but not distinct. Excretory pore is well marked; it is usually a little distance below the posterior end of the œsophagus, but at times level with the posterior end. Rectum and anal opening are prominent.
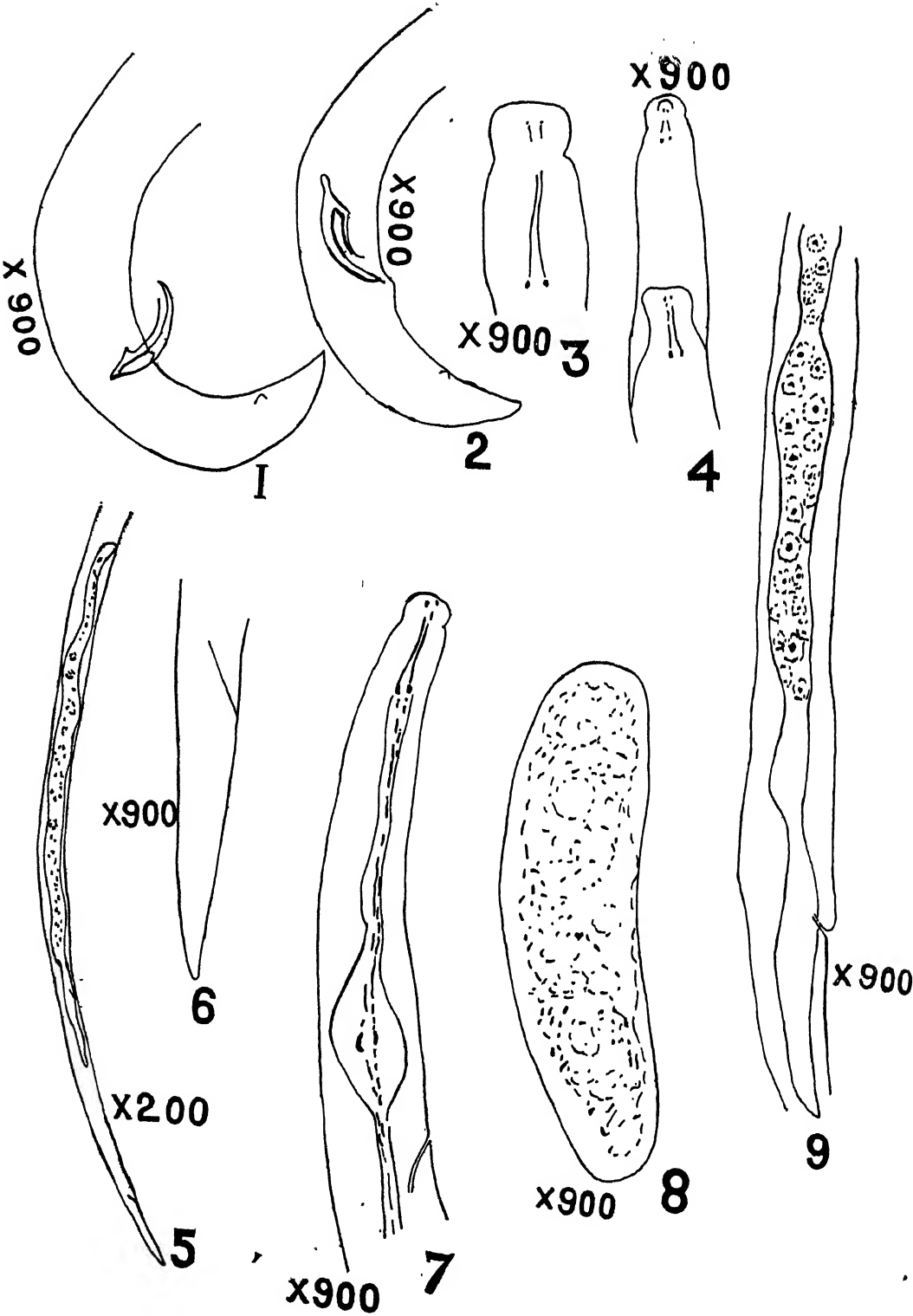
Female tail is tapering straight and conical; it has three fine stiff minute hairlike appendages, which when they are in close proximity or pressed together make the tail look sharply pointed. Vulva is well marked; the anterior lip is rounded and conspicuous; the opening forms a prominent slit. Vagina is directed inwards and forwards. Posterior uterine sac extends towards rectum about 40–50 $\mu$ from the vulva (Figs. 5 and 9). A constriction separates uterus from ovary; uterus is straight. Ovary is anterior, single, and not reflexed, but the apical end is at times slightly curved.

Male tail in fixed specimens is ventrally curved, almost semi-circular. It has two spicules; they are curved, thorn-shaped, and sharply pointed; the dorsal spicule consists of two pieces; the ventral is single and smaller than the dorsal (Figs. 1 and 2). Two caudal papillæ are present, one ad-anal which is prominent and the other just behind the median point of the tail which may be indistinct; tail has one or two minute stiff appendages; testis is single, outstretched and not reflexed.

*Dimensions.* Female:—length 0·4–0·8 mm.; width 0·01–0·035 mm.; stylet 10–15$\mu$; $\alpha$ 48–22; $\beta$ 11–5; $\gamma$ 20–8; $\delta$ 4$v$–3; V 64–80%.

Male:—length 0·5–0·62 mm.; width 0·01–0·02 mm.; $\alpha$ 45–18; $\beta$ 12–3; $\gamma$ 23–12·7; dorsal spicules 13·2–10·2 $\mu$; ventral spicules 7·7–5·1 $\mu$.

Eggs are sausage-shaped; one end is more broadly rounded than the other. They measure 71·0–82·0 × 15·0–20·5 $\mu$. They are found in an unsegmented condition; very few eggs have been observed. They have not been seen inside the female nemas.

Larvæ resemble female adults in shape. The tail in the last larval stage has appendages similar to those of an adult female. Oesophageal glands of a larva are more conspicuous than those of an adult. Stylet with two basal swellings (Fig. 4), œsophageal bulb and rectum are prominent.

*Aphelenchoides* sp. on rice is ectoparasitic; on the immature branch of a young inflorescence the nema is found between the membraneous parts of spikelets; in the empty grain with white glumes it lives on the inner side of the glumes, on stigmas and anthers; it has not been found on the outside of the glumes of the sterile flower or within their tissues; *loc. cit.* it is rarely found inside the flowerless distorted papery glumes. It has been found also in the axils of leaves.

### Summary.

A new disease of rice, considered to be caused by a nematode, belonging to the genus *Aphelenchoides* is described.

Plants infested with the nema produce " light" ears ; the inflorescence is attacked while it is still within its boot. A diseased panicle cannot be usually differentiated from a healthy one, till it comes out of the enveloping sheath. Some of the branches of the diseased inflorescence completely fail to develop ; a few spikelets on normally developed branches have either sterile flowers with white glumes, which may be distorted, or the spikelets may be aborted ; there is no rotting or shrinking of the peduncle of the infested inflorescence, as in the case of " ufra " disease of rice in Bengal. The glumes of healthy flowers may be spotted ; the spotting takes place when the flowers are still enclosed within the boot ; it does not affect the normal development of the flower.

The nema has been found inside the white glumes of sterile flowers and between the floral parts of undeveloped flower buds. It has been observed in specimens collected in 1935 from various parts of the Central Provinces, and also from herbarium specimens of " light " ears collected in 1934.

If the atmospheric humidity, due to rainfall, is high at the time the inflorescence is still within its enveloping sheath the flower buds are vulnerable to an attack by the nema. Early varieties of rice, like Ludka, are therefore susceptible to this disease if there are occasional showers of rain in October when the plants are heading. This explains why the incidence of " light " ears is sporadic.

Varieties like Ludka, E.B. 17, Pisso and Luchai 21 in certain seasons have a very poor growth due to the dying of outer leaves from tip downwards and of tillers. The various fungi and bacteria isolated from dying leaves and tillers, and sterile spikelets of " light " ears have failed to reproduce the disease. From axils of dying leaves and from dying tillers a nema similar to that present in sterile flowers has at times been found, it is therefore considered that the dying of leaves and of tillers may also be due to the same nema, *Aphelenchoides* sp., which causes " light " ears.

A technical description of the nema, *Aphelenchoides* sp., is given.

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## EXPLANATION OF FIGURES.

Figs. 1 & 2.—Male tail. Spicules in Fig. 1 are extended. ×900.
Fig. 3.—Head of an adult. ×900.
Fig. 4.—Anterior end of a molting larva. ×900.
Fig. 5.—Female genitals. ×200.
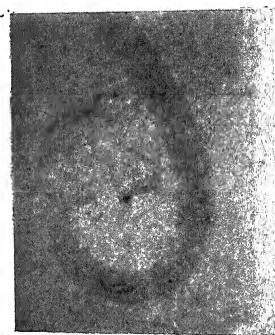
10          11          12          13

FIG.  6.—Female tail.   ×900.

FIG.  7.—Anterior end of an adult.   ×900.

FIG.  8.—Egg.   ×900.

FIG.  9.—A part of the female genitals.   ×900.

FIG. 10.—Young inflorescence infested with *Aphelenchoides* sp.

FIG. 11.—Female *Aphelenchoides* sp.

FIG. 12.—A male *Aphelenchoides* sp.

FIG. 13.—The posterior end of a male.

# ESTIMATION OF NITROGEN BY FUMELESS DIGESTION. PART III.

## Extension of Chromo-Sulphuric Acid Digestion to include Large Quantities of Nitrates.

By C. R. HARIHARA IYER, M.A.

AND

R. RAJAGOPALAN, B.Sc. (HONS.).

(*From the Department of Biochemistry, Indian Institute of Science, Bangalore.*)

IT was shown in the previous communications (Harihara Iyer and Rajagopalan, 1935 ; Harihara Iyer, Rajagopalan and Subrahmanyan, 1936) that the total nitrogen in soils and biological materials can be estimated by a modified method of chromo-sulphuric acid digestion followed by reduction with sulphite and zinc. Attention was also drawn to the fact that the estimates thus obtained will include only small quantities of nitrate (upto 50 parts per million) and that some preliminary reduction may be needed if the material contains larger quantities. The present paper relates to an extension of the original method for the inclusion of fairly large quantities of nitrates (upto 300 parts per million) in the estimate of total nitrogen.

*Experimental.*

Some preliminary experiments showed that if mercuric oxide is not added to the digesting mixture, then nitrate-nitrogen in soils can be quantitatively estimated by treatment with sulphite followed by zinc. The following (Table I) is an illustration :—

### TABLE I.

| | Soil (Bangalore-laterite) alone (Control) | Soil + Nitrate nitrogen (in parts per million) | | | |
|---|---|---|---|---|---|
| | | 50 | 100 | 200 | 300 |
| | | Total nitrogen (in parts per million) | | | |
| Expected | 552 | 602 | 652 | 752 | 852 |
| Found | 552 | 600 | 654 | 749 | 850 |

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The soil used in the foregoing experiment was free from halides ; but, unfortunately, many soils and biological materials contain chlorides, so the presence of the mercury salt is necessary to avoid loss of nitrogen in elementary form.     Any modification that may be proposed should, there-fore, be applicable in presence of mercury salts.

On adding zinc, after treatment with just sufficient quantity of sulphite to reduce the unused chromic acid, it was found that the action was not generally vigorous.  Even boiling for a considerable period did not appre-ciably improve the rate.  This was traced to the formation of protective coats of metallic mercury around unattacked particles of zinc.  The particles were saturated with hydrogen and in consequence, tended to float ineffectively at the surface of the medium.

With a view to completely eliminating the interference of mercury, various treatments were tried, and it was found that even alkali sulphite, added in sufficient excess, would be quite effective for the purpose. If, instead of stopping when the colour turns pale blue, the addition of sulphite is continued until a greyish black precipitate is formed, then the interfering mercury is mostly removed from the sphere of action.  The subsequent dissolution of zinc proceeds fairly rapidly and even large quantities of added nitrates can be quantitatively estimated.

TABLE II.

| Description of soil | Soil alone | Soil + Nitrate (as p.p.m. of nitrogen) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 50 | 100 | 150 | 200 | 250 | 300 |

Total nitrogen (in p.p.m.) as estimated

| Description of soil | Soil alone | 50 | 100 | 150 | 200 | 250 | 300 |
|---|---|---|---|---|---|---|---|
| Nagpur-Black cotton     .. | 428 | 475 (47) | 520 (92) | 569 (141) | 632 (204) | 680 (252) | 721 (293) |
| Bangalore-Laterite     .. | 552 | 600 (48) | 654 (102) | 700 (148) | 749 (197) | 798 (246) | 850 (298) |
| Mandalay-Alluvial     .. | 340 | 387 (47) | 440 (100) | 486 (146) | 544 (204) | 582 (242) | 636 (296) |

(The bracketed figures represent the quantities of nitrates as estimated.)

It is well known (Sreenivasan, 1935) that nitrates cannot be quantitatively reduced by treatment with zinc alone, so it appeared probable that the presence of chromium in the medium or pre-treatment with sulphite was in some way responsible for the increased efficiency of reduction.  With a view to throwing some light on this aspect of the problem, some experiments

were carried out treating acidified nitrate solutions with zinc (2 g.) (*a*) in presence of a chromium salt [$Cr_2(SO_4)_3$, 3 g.] and (*b*) after treatment with sulphite ($Na_2SO_3$, 1–2 g.).

TABLE III.

*Effect of addition of chromium salt on the efficiency of reduction.*

| | | Nitrate-nitrogen (in terms of c.c. of N/30 alkali) | | | |
|---|---|---|---|---|---|
| Taken | .. .. | 2·0 | 3·0 | 4·0 | 6·0 |
| Found | .. .. | 1·8 | 2·65 | 3·5 | 5·1 |

TABLE IV.

*Effect of pre-treatment with sulphite on the efficiency of reduction.*

| | | Nitrate-nitrogen (in terms of c.c. of N/30 alkali) | | | |
|---|---|---|---|---|---|
| Taken | .. .. | 1·0 | 2·0 | 4·0 | 6·0 |
| Found | .. .. | 0·95 | 1·90 | 3·6 | 5·4 |

Although the foregoing treatments were not individually very effective, they did, nevertheless, yield quantitative results when combined together.

TABLE V.

*Effect of addition of chromium salt followed by treatment with sulphite.*

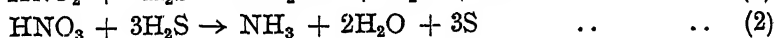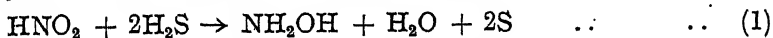| | | Nitrate-nitrogen (in terms of c.c. of N/30 alkali) | | | | | |
|---|---|---|---|---|---|---|---|
| Taken | .. .. | 1·0 | 2·0 | 3·0 | 4·0 | 5·0 | 6·0 |
| Found | .. .. | 0·95 | 2·0 | 2·90 | 4·05 | 5·0 | 6·0 |

Addition of zinc after treatment with sulphite in acid medium may naturally be expected to yield some quantity of hydrogen sulphide. Boiling may remove the major part of the sulphur dioxide, but some will always be left out and undergo reduction immediately after addition of zinc. With a view to determining the effect of hydrogen sulphide on the efficiency of reduction, aqueous, acid solutions of nitrate were treated with chromium sulphate (2–3 g.) followed by potassium sulphide (1–2 g.) and zinc (2 g.).

TABLE VI.

*Effect of addition of chromium salt followed by pre-treatment with alkali sulphide.*

| | Nitrate-nitrogen (in terms of c.c. of N/30 alkali) | | | |
|---|---|---|---|---|
| Taken .. .. | 2·0 | 4·0 | 5·0 | 6·0 |
| Found .. .. | 2·1 | 3·95 | 4·9 | 6·0 |

It may be seen that pre-treatment with sulphide is as efficient as that with sulphite. Since both the treatments result in the ultimate formation of hydrogen sulphide in the medium, the beneficial effect may be traced to that product.

It is well known that the reduction of nitrate by zinc in acid medium results in the intermediary formation of nitrous acid. If the mixture is boiled (as is usually done to hasten reduction), a part of the nitrite-nitrogen is lost directly as gases ($NO_2$ and $NO$), while a further quantity may react with other intermediate products that may be formed during reduction in the medium causing loss of nitrogen in the elementary form. If hydrogen sulphide is present in the medium, it would react with nitrous acid forming hydroxylamine and ammonia (Bagster, 1928).

$$HNO_2 + 2H_2S \rightarrow NH_2OH + H_2O + 2S \qquad .. \qquad .. \quad (1)$$
$$HNO_3 + 3H_2S \rightarrow NH_3 + 2H_2O + 3S \qquad .. \qquad .. \quad (2)$$

The resulting sulphur is again reduced by hydrogen forming hydrogen sulphide. In this manner, even a comparatively small quantity of sulphur dioxide or hydrogen sulphide is sufficient to prevent the accumulation of nitrous acid in the medium.

The action of hydrogen sulphide may be regarded as being more or less catalytic, no more than traces of that gas being required for reduction of even 300 p.p.m. of nitric-nitrogen. Larger quantities of that gas are indeed inconvenient and produce offensive smell. On the other hand, removal of the last traces of hydrogen sulphide by careful addition of dichromate impairs the efficiency of reduction and yields lower estimates of nitrate.

The rôle of chromium in improving the efficiency of reduction is not clear. It is probable that it combines with the hydroxylamine, thus protecting it from interaction with even the traces of nitrous acid which may be free. Finally, hydroxylamine is also reduced, yielding ammonia.

*Procedure for treating the Chromo-sulphuric acid digest.*—In usual practice, the formation of the greyish black precipitate is an indication of the removal

of most of the interfering mercury. If, by any chance, the quantity does not prove sufficient and a considerable portion of the unattacked zinc floats on top, then the heating may be stopped momentarily and a further quantity of sulphite added. This results in the immediate removal of the mercury, allowing the reduction of nitrate to proceed normally. If necessary, a further quantity of zinc may also be added to hasten the reduction.

It is not desirable to leave more than traces of sulphur dioxide in the medium at the time of addition of zinc : otherwise, most of the hydrogen produced by the action of acid on zinc is used up for the reduction of sulphurous acid to hydrogen sulphide and very little is available for the reduction of nitrate. In this manner, the efficiency of reduction of nitrate may be lowered considerably. The following results (Table VII) will illustrate the above.

TABLE VII.

*Effect of addition of zinc before boiling off the major part of the dissolved sulphur dioxide.*

| | Nitrate-nitrogen (in terms of c.c. of N/30 alkali) | | | |
|---|---|---|---|---|
| Taken .. .. | 1·0 | 2·0 | 3·0 | 4·0 |
| Found .. .. | 0·95 | 1·4 | 1·6 | 1·9 |

*General procedure for quantitative reduction of nitrate by zinc.*—Although the foregoing results relate primarily to reduction of chromic acid digests, they could, nevertheless, be applied to the estimation of nitrates by zinc in acid media. The procedure will consist in adding a chromium salt (preferably chromium sulphate, 3 g.) to a sulphuric acid solution of nitrate followed by addition of sulphite (2 g.). The mixture is then boiled for 5 minutes and zinc (2 g.) added. After further boiling for about 5 to 10 minutes, it may be cooled and distilled with excess of alkali in the usual way.

*Mechanism of the action of reduced iron.*—Previous workers (Ulsch, 1891 ; Olsen, 1927) have drawn attention to the fact that there is no intermediary formation of nitrous acid during reduction of nitrate by reduced iron. The commoner samples of reduced iron contain ferrous sulphide, so it is probable that even if nitrous acid is formed during reduction, it would immediately react with the hydrogen sulphide also formed in the medium. A further observation of interest is that ferrous sulphate affords further protection in the same way as the chromium salt.

TABLE VIII.

*Effect of addition of ferrous sulphate combined with pre-treatment with alkali sulphide.*

| | Nitrate-nitrogen (in terms of c.c. of N/30 alkali) | | | |
|---|---|---|---|---|
| Taken .. .. | 1·0 | 3·0 | 5·0 | 6·0 |
| Found .. .. | 1·0 | 2·9 | 4·9 | 6·0 |

It would thus appear that the action of reduced iron is similar to the combined effect of chromium salt and sulphide.

*Summary.*

(1) The incomplete reduction of nitrate (over 50 parts per million) in the chromo-sulphuric acid digest by zinc is traceable to the presence of the mercury salt in the digesting mixture. The mercury forms a coat of hydride around unattacked zinc and thus prevents further action with acid.

(2) The interference of mercury can be eliminated and accurate estimates of nitrates in soils (upto 300 parts per million) obtained by adding extra quantity of sodium sulphite to the digest until a black precipitate is obtained. The suspension is then raised to boil and treated with zinc in the usual way.

(3) The efficiency of zinc in reducing nitrate in the digest is traceable to the joint action of chromium and sulphite. On treatment of acid with zinc the latter forms hydrogen sulphide which is directly responsible for the removal of small quantities of nitrous acid that may be formed during reduction. The mechanism of the related processes has been discussed.

(4) The commoner samples of reduced iron contain ferrous sulphide, so that the non-formation of nitrous acid during reduction of nitrate by that reagent is traceable to hydrogen sulphide. The ferrous salt present in solution behaves in a manner similar to the chromium salt and thus prevents loss of nitrogen during reduction.

Our thanks are due to Professor V. Subrahmanyan for his keen interest in the work.

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# STUDIES IN THE FAMILY ALISMACEÆ.

### IV. *Alisma plantago* L.; *Alisma plantago-aquatica* L. and *Sagittaria graminea* Mich.

BY B. M. JOHRI.

*(From the Department of Botany, Agra College, Agra.)*

## *Introduction.*

THE first account of the embryo sac of *Alisma plantago* was published by Ward in 1880. Bessey's (1898) work on *Alisma plantago-aquatica* deals mainly with the development of the ovule. After Ward no less than four authors—Fischer (1880) ; Schaffner (1896).; Nitzschke (1914) ; and Dahlgren (1928)—have investigated *Alisma plantago*.

Ward (1880) writes that the megaspore mother cell divides into two cells, of which the upper divides once again but the two cells thus formed degenerate. The nucleus of the lower cell divides thrice and produces a typical eight-nucleate embryo sac. Fischer (1880) noted in the same year that the upper of the two cells remains undivided and degenerates while the lower develops into an eight-nucleate embryo sac. Schaffner (1896) reported that the archesporial cell cuts off a wall cell, and the megaspore mother cell develops directly into an eight-nucleate embryo sac. Nitzschke (1914) observed that the megaspore mother cell produces four free nuclei of which three are cut off at the top by a wall and degenerate, and the remaining nucleus divides thrice to produce an eight-nucleate embryo sac. Sometimes, however, Nitzschke found only two nuclei at the chalazal end instead of four. Dahlgren's (1928) work is the most detailed and he points out that all the previous accounts of the development of the female gametophyte in this plant were erroneous. He finds that the hypodermal archesporial cell directly develops into a megaspore mother cell which divides into two cells of which the upper soon degenerates (this is a dyad cell and not a wall cell). The lower cell divides twice to form a four-nucleate embryo sac. After this the two chalazal nuclei do not divide further and thus a six-nucleate embryo sac is formed. The following is a diagrammatic representation of the development of the embryo sac in *Alisma plantago* as described by the above authors :—

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| megaspore mother cell | 1st division | 2nd division | 3rd division | 4th division | 5th division |
|---|---|---|---|---|---|
| Ward (1880) | | | | | |
| Fischer (1880) | | | | | |
| Schaffner (1896) | | | | | |
| Nitzschke (1914) | | | | | |
| Dahlgren (1928) | | | | | |

From the above review it is clear that no less than four authors—Ward, Fischer, Schaffner and Nitzschke—reported an eight-nucleate embryo sac in *Alisma plantago*. I find that the course of development described by Dahlgren is entirely correct but it will be shown during the course of this paper that seven-nucleate embryo sacs are also found and the possibility of eight-nucleate embryo sacs cannot be denied, though their occurrence must be very rare. In this paper I shall record my observations on *Alisma plantago* L., as well as two other plants of this family—*Alisma plantago-aquatica* L. and *Sagittaria graminea* Mich.

## Material and Methods.

checking the identifications of *Alisma plantago-aquatica* L. and *Sagittaria graminea* Mich.

The Materials sent are as follows :—

| Name of plant | Sender | Collected from | Fixing fluid |
|---|---|---|---|
| 1. *Alisma plantago* L. | .. Dracinschi | Cernăuti | Nawaschin's fluid |
| 2. *Alisma plantago-aquatica* L. | ... Pfeiffer | Yonkers | ,, |
| 3.              ,, | Francini | Pisa | ,, |
| 4. *Sagittaria graminea* Mich. | .. Gager | Brooklyn | ,, |

The usual methods of dehydration and imbedding were followed. Sections were cut 4–15 microns thick and stained in Haïdenhain's Iron-alum Hæmatoxylin. Alcoholic Fast Green was often used as a counter-stain since it proved to be very helpful in tracing the pollen tubes.

*Alisma plantago* L.

*Embryo sac.*—My observations entirely agree with those of Prof. Dahlgren up to the formation of the four-nucleate embryo sac. I have, however, noted some abnormalities. In one case three megaspore mother cells were seen in the same nucellus (Figs. 1 *a* and *b*); in another case the primary chalazal nucleus of the two-nucleate embryo sac had degenerated almost immediately after its formation (Fig. 2).[1]

After the four-nucleate stage only the two micropylar nuclei usually divide again, but Figs. 3 and 4 show that *three nuclei* are preparing for division, and in Fig. 3 the lowest chalazal nucleus appears to have fragmented into two parts. In Fig. 5 there are three mitotic spindles in the telophase, while the fourth nucleus lies undivided at the bottom. The embryo sacs thus formed are seven-nucleate (Fig. 7), though normally only six-nucleate embryo sacs occur (Fig. 6). Eight-nucleate embryo sacs were not seen, but their occurrence in rare cases cannot be denied, specially in view of the fact that they have been found in other plants of this family normally reported to have only six-nucleate embryo sacs—*Sagittaria sagittifolia* (Dahlgren, 1928 ; Johri, 1934/35), *S. guayanensis* and *S. latifolia* (Johri, 1935/36), *Limnophyton obtusifolium* (Narasimha Murthy, 1934 ; Johri, 1935) and *Alisma plantago-aquatica* (Johri, 1936).

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[1] This would probably result in a five-nucleate embryo sac, as found in *Butomopsis lanceolata* (Johri, 1936).
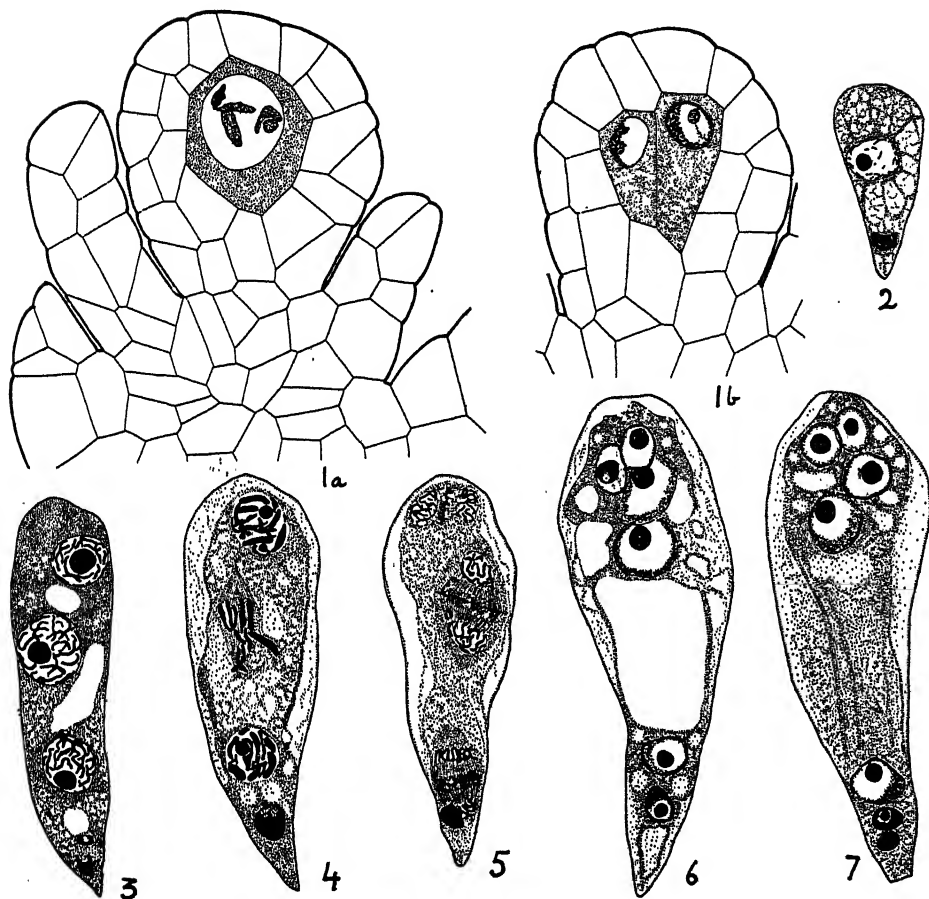
Figs. 1–7.—*Alisma plantago* L. × 750. Figs. 1*a* and 1*b*.—Adjacent sections of an ovule with three megaspore mother cells. Fig. 2.—A young two-nucleate embryo sac with the primary chalazal nucleus degenerated. Fig. 3.—Three of the four nuclei of the embryo sac preparing for division and the lowest nucleus has fragmented. Figs. 4–5.—Stages that would result in the formation of seven-nucleate embryo sacs. Fig. 6.—Six-nucleate embryo sac. Fig. 7.—Seven-nucleate embryo sac.

### *Alisma plantago-aquatica* L.

*Microsporogenesis and male gametophyte.*—A group of hypodermal archesporial cells differentiates in each lobe of the young anther. The endothecium, a single ephermeral middle layer and a tapetum, which gives rise to a periplasmodium, are formed as described in my earlier papers on *Limnophyton obtusifolium* (Johri, 1935) and *Sagittaria guayanensis* (Johri, 1935/36). The microspore nucleus divides to produce a tube and a generative cell and the latter divides again to form two *male cells* which often become sickle-shaped at the time of shedding of the pollen grains.

8    9    10    11    12    13    14    15    16
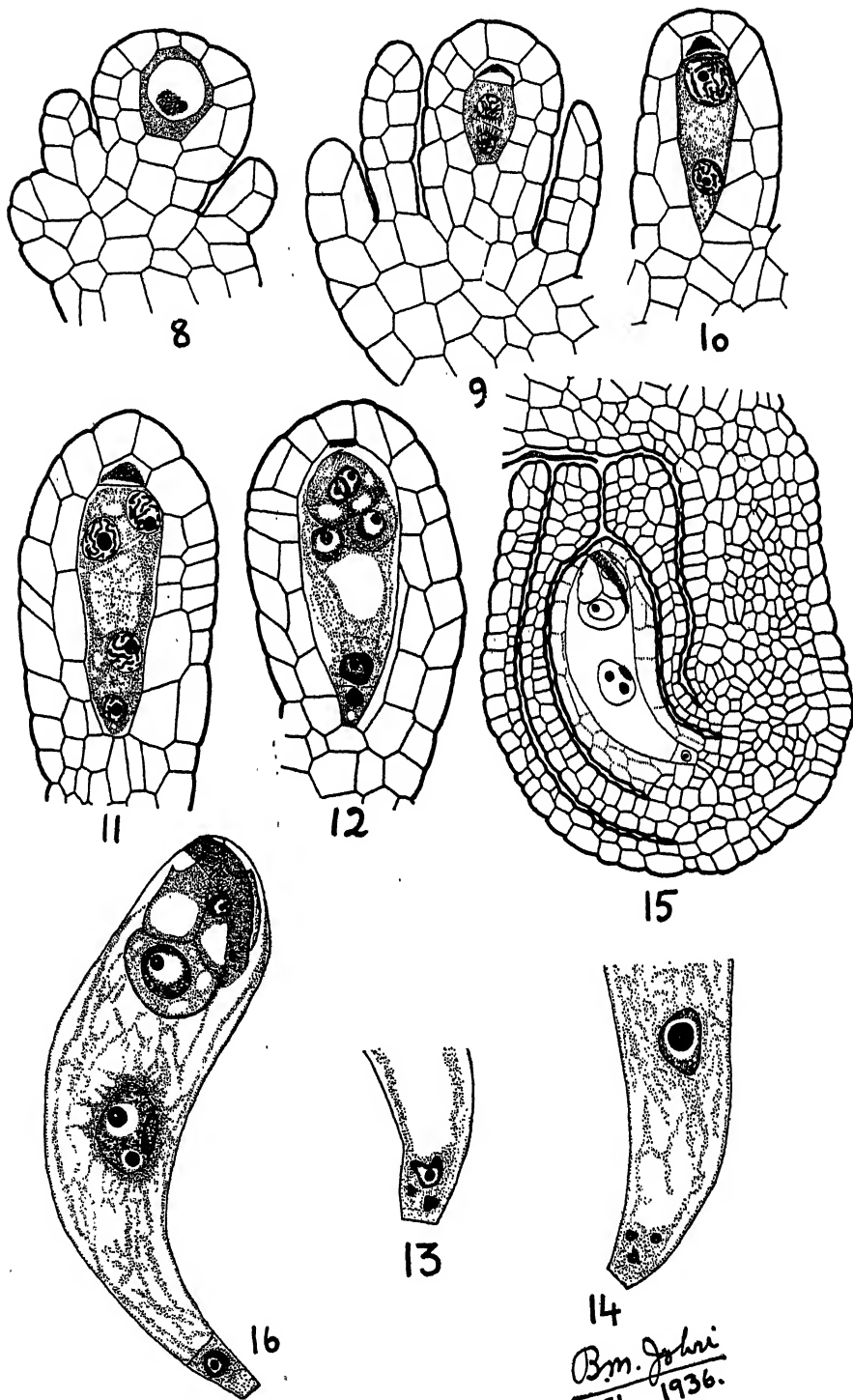
B.m. Johri
DEL. 1936.

FIGS. 8–16.—*Alisma plantago-aquatica* L. $\times$ 500. Fig. 8.—Megaspore mother cell. Fig. 9.—Out of the two dyad cells formed from the megaspore mother cell, the upper has degenerated and the division of the lower has been followed by the laying down of an ephemeral cell-plate. Figs. 10–12.—Two-, four-, and six-nucleate embryo sacs. Figs. 13–14.—Lower ends of seven- and eight-nucleate embryo sacs. Figs. 15–16.—Anatropous ovule with the embryo sac at the time of fertilisation.

*Megasporogenesis and female gametophyte.*—A hypodermal megaspore mother cell differentiates in the young nucellus at about the same time the two integuments make their appearance (Fig. 8). The megaspore mother cell divides into two cells of which the upper soon degenerates and the lower divides again ; occasionally an ephemeral cell-plate is observed on the spindle of this nuclear division (Fig. 9) but it disappears very soon. The two- and four-nucleate stages are passed through in the normal way and the degenerated remains of the upper dyad cell can be made out in the form of a darkly staining cap at the upper end of the embryo sac (Figs. 10 and 11). The two micropylar nuclei divide once but the chalazal remain undivided in most cases so that a six-nucleate embryo sac is formed. Out of the upper four nuclei, three form the egg-apparatus while the fourth is the upper polar nucleus. Of the two chalazal nuclei one functions as the lower polar nucleus and the other represents the single antipodal nucleus which may often be cut off from the rest of the embryo sac by a delicate cell membrane (Fig. 12). The synergids are hooked and possess a filiform apparatus.

Sometimes one of the two chalazal nuclei, or both of them, may divide once so that three or four nuclei are formed at the lower end of the embryo sac, one of which always functions as the lower polar nucleus and the remaining two or three are the antipodal nuclei (Figs. 13–14). Thus seven- and eight-nucleate embryo sacs also occur in *Alisma plantago-aquatica.*

*Fertilisation.*—At the mature embryo sac stage, the inner integument becomes specially thick at the micropylar end, thus leaving a very narrow passage for the pollen tube (Fig. 15). One of the synergids is always disorganised. Actual stages in fertilisation were not observed but several embryo sacs were seen in which triple fusion was in progress (Fig. 16).

*Endosperm and Embryo.*—The endosperm is free nuclear and the development of the embryo corresponds to the well-known Alisma-type. The nucellus begins to disorganise, when the embryo sac is ready for fertilisation and at the same time the inner layer of cells of the inner integument becomes richly protoplasmic and assumes the appearance of an integumentary tapetum. A corresponding observation has also been made by Dahlgren (1928) in *Alisma plantago.*

*Sagittaria graminea* Mich.

Earlier stages of development were not available and only mature embryo sacs and stages in fertilisation and embryogeny could be studied.

*Embryo sac.*—Most of the embryo sacs are six-nucleate (Fig. 17) and there can be hardly any doubt that they arise in the same manner as in *Sagittaria sagittifolia* (Dahlgren, 1934). Sometimes one of the two lower nuclei also divides and thus two antipodal cells are present (Fig. 18). Occasionally the antipodal nuclei show an appearance that is suggestive of fragmentation (Fig. 19), as also reported here for *Alisma plantago*. It is particularly noteworthy that frequently one or both the synergids assume an egg-like appearance, with the nucleus at the lower end and a vacuole at the upper (Figs. 20–21). Among other plants where the synergids show a similar behaviour are *Aconitum napellus* (Osterwalder, 1898); *Myricaria germanica* (Frisendahl, 1912); *Delphinium elatum* (Persidsky, 1914); *Moringa oleifera* (Puri, 1934/35) and *Gisekia pharnaceoides* (Joshi and Rao, 1936).

*Fertilisation.*—Many stages in double fertilisation were observed. One of the synergids is always disorganised by the pollen tube and the second disappears soon after. In one embryo sac, in which (Fig. 22) two pollen tubes had entered, two male gametes ($m_1$, $m_2$) were seen in the process of fusion with the egg and polar nucleus respectively; while two others ($m_3$, $m_4$) from the second pollen tube were lying near the egg. The fact that a distinct hyaline cytoplasmic sheath can be seen around the latter right up to the time of their discharge in the embryo sac is of interest.

Schaffner (1897) stated that in *S. variabilis* (really *S. latifolia*[2]) one of the sperm nuclei never leaves the pollen tube so that the fusion nucleus is not fertilised. I have sectioned some flowers of this species and I have definitely seen a male gamete taking part in triple fusion (Fig. 26). It is to be noted that Schaffner's paper appeared an year before Nawaschin's (1898) discovery of double fertilisation in angiosperms.

*Endosperm and Embryo.*—The endosperm is of the 'Helobiales-type' (Fig. 23), a wall being laid down between the two daughter nuclei formed after the first division of the primary endosperm nucleus. The upper of the two daughter nuclei migrates into the big micropylar chamber and undergoes many free nuclear divisions while the lower divides only once or twice and the resulting nuclei ultimately degenerate in the small chalazal chamber. Fig. 25 shows an interesting case in which the oospore has divided by a transverse wall, the endosperm nucleus of the micropylar chamber has divided

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[2] I am grateful to Dr. Norma E. Pfeiffer for kindly supplying some fixed flowers of *S. latifolia* Willd.
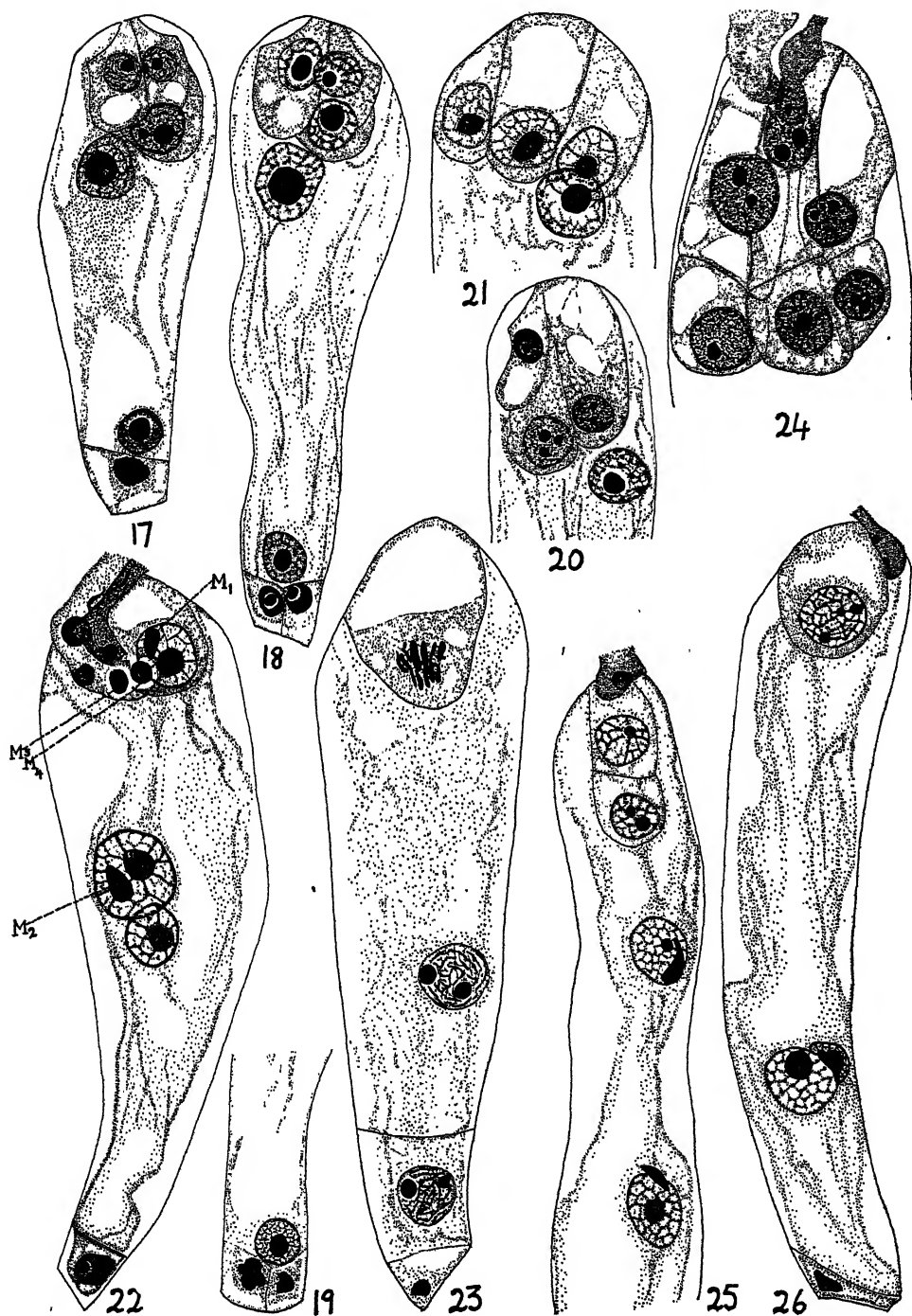
FIGS. 17–25.—*Sagittaria graminea* Mich.; and FIG. 26.—*S. latifolia* Willd. Figs. 17–24. $\times$ 750.
  Figs. 25–26. $\times$ 600. Figs. 17–18.—Six- and seven-nucleate embryo sacs. Fig. 19.
  —Lower end of a seven-nucleate embryo sac. Fig. 20.—Upper part of an embryo
  sac in which one of the synergids has an egg-like appearance. Fig. 21.—Same,
  both the synergids have become egg-like. Fig. 22.—Embryo sac showing double
  fertilisation and one extra pollen tube (m = male gamete). Fig. 23.—First
  division of the oospore. Fig. 24.—Three two-celled pro-embryos, two of which
  have developed from the synergids. Fig. 25.—Upper part of the embryo sac
  with a two-celled pro-embryo and one male gamete attached to each of the two
  endosperm nuclei. Fig. 26.—Embryo sac of *S. latifolia* showing triple fusion.

to form two free nuclei and a male gamete is seen in close union to each of
these. It seems that two pollen tubes had entered this embryo sac one after
the other and after normal double fertilisation the two supernumerary male
nuclei attached themselves to the endosperm nuclei. A similar figure has
also been drawn by Narasimha Murthy (1934, Fig. 45) in *Limnophyton obtusi-
folium*, but he interprets it as an abnormal case in which one male nucleus is
in contact with each of the two polar nuclei.

The primary endosperm nucleus usually divides a little earlier than the
fertilised egg (Fig. 23) and the development of the embryo corresponds
in essential respects to what has already been described for *S. sagittifolia*
(Souèges, 1931).

A very interesting case of polyembryony was met with in an ovule which
showed three two-celled pro-embryos and the remnants of two pollen tubes
at the micropylar end of the embryo sac (Fig. 24). It seems reasonable to
conclude that the two extra embryos have arisen from the two synergids
which were fertilised by the two male gametes discharged from the second
pollen tube. The fact (already mentioned before) that occasionally the
synergids take up the form of an egg (Figs. 20–21) gives further support to
this view. In the order Helobiales, Guignard (1901) reported an exactly
similar phenomenon in *Najas major*. A comprehensive list of plants in which
the synergids become fertilised and produce embryos is given by Schürhoff
(1926 ; p. 320) and Dahlgren (1927, p. 174).

*Summary.*

*Alisma plantago* L.—The pollen grains are three-nucleate with two male
cells. As reported by Dahlgren (1928) the development of the embryo sac
is of the 'Scilla-type', but besides the usual six-nucleate embryo sacs, seven-
nucleate embryo sacs have also been seen and there is a probability that in
rare cases eight-nucleate embryo sacs also occur.

*Alisma plantago-aquatica* L.—Stages in microsporogenesis and develop-
ment of the male gametophyte do not show any features of special interest.

The development of the embryo sac corresponds to that of *Alisma plantago* (Dahlgren, 1928), but seven- or eight-nucleate embryo sacs are also formed occasionally. The endosperm is free nuclear.

*Sagittaria graminea* Mich.—Six-nucleate embryo sacs are the rule, but some were found to have seven nuclei. One or both the synergids sometimes assume an egg-like appearance and develop into embryos. More than one pollen tube may enter the embryo sac. The endosperm is of the 'Helobiales-type' and the embryo follows the same course of development as described for *S. sagittifolia* (Souèges, 1931).

My heartfelt thanks are due to Dr. P. Maheshwari for his kind help and useful suggestions throughout the course of this work. I am also grateful to Messrs. Bahadur Singh and S. P. Capoor for preparing some of the diagrams.

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* The original papers were not available to me.

# THE LIFE-HISTORY OF
## *BUTOMOPSIS LANCEOLATA* KUNTH.[1]

BY B. M. JOHRI.

*(From the Department of Botany, Agra College, Agra.)*

### *Introduction.*

THE HELOBIALES have always been regarded as a very primitive order of the Angiosperms and recently, Hutchinson (1934) has remarked that the *Butomaceæ* and *Alismaceæ* are the most primitive families of the monocotyledons, showing significant resemblances with the *Helleboroideæ* and *Ranunculoideæ* of the dicotyledons.

The embryology of only three members of the family *Butomaceæ* has so far been investigated : *viz.*, *Butomus umbellatus* (Ward, 1880 ; Holmgren, 1913), *Limnocharis emarginata* (Hall, 1902 ; Nitzschke, 1914) and *Hydrocleis nymphoides* (Suessenguth, 1921). Of these, the accounts of *Limnocharis* and *Hydrocleis* are not very satisfactory and a reinvestigation of these genera is very much to be desired. The only detailed work is that of Holmgren (1913) on *Butomus umbellatus* but even this may reveal some interesting facts on further investigation.

### *Previous Work.*

Ward (1880) investigated *Butomus umbellatus* and found a linear or a T-shaped tetrad of megaspores of which the lowest gives rise to a six- or eight-nucleate embryo sac. He states that the megaspore nucleus divides twice resulting in a four-nucleate embryo sac. All the four nuclei usually divide once again resulting in eight, but sometimes the two chalazal nuclei remain undivided so that only six nuclei are present in the mature embryo sac. Holmgren's (1913) work on the same plant is more detailed and well illustrated. The embryo sac was found to be of the normal type and Ward's statement, that sometimes there are only two nuclei at the chalazal end, is regarded by him as inaccurate.

Hall (1902) worked on *Limnocharis emarginata* and says that, " the large cell left after the formation of the tapetum becomes the embryo sac

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[1] I am indebted to the Forest Botanist, Dehra Dun, for the identification of the plant. The generic name is *Tenagocharis* in Engler and Prantl (1889).

without further division," *i.e.*, the development is of the "Lilium type". The mature embryo sac is only five-nucleate with a normal group of four nuclei at the micropylar end and a single antipodal nucleus at the chalazal end. Nitzschke (1914) has criticised Hall's observations and pointed out that the primary chalazal nucleus (of the two-nucleate embryo sac) divides once, and sometimes twice, resulting in six- or eight-nucleate embryo sacs.

In his paper entitled "Beiträge zur Frage des systematischen Anschlusses der Monokotylen," Suessenguth (1921) reports a normal eight-nucleate embryo sac in *Hydrocleis nymphoides*. The accompanying illustrations would, however, fail to convince a critical observer and a confirmation of several points is necessary before they can be finally accepted. His Fig. '3e' shows a hypodermal archesporial cell. A megaspore tetrad was not actually seen, but the author infers from the appearance of some of the older stages that this does occur.[2] Figs. '*i–m*' would give the impression that after the division of the megaspore nucleus the two daughter nuclei do not move apart to the poles and at the four-nucleate stage all the nuclei are situated at the micropylar end. Further stages in development are missing and we at once pass on to a fully organised eight-nucleate embryo sac in Fig. '*n*'. It is difficult to understand how the three antipodal cells could have arisen suddenly at this stage.

### *Material and Methods.*

The material used for this investigation was collected at my request by Mr. A. C. Joshi of the Benares Hindu University, to whom my best thanks are due. Formalin-acetic-alcohol and Nawaschin's fluid were the only fixatives used and the latter gave very satisfactory results. The usual methods of dehydration and imbedding were followed. Sections were cut 4–12 microns thick and stained in Heidenhain's iron-alum hæmatoxylin. Some of the slides, prepared for a study of the development of the microspores were stained in Delafield's hæmatoxylin to bring out the special wall. Alcoholic Fast Green was often used as a counter-stain since it proved to be very helpful in tracing the course of the pollen tubes.

### *The Flower.*

The floral organisation is of the simplest type. There are six perianth leaves in two whorls of three each, six to eight stamens with broad and flattened filaments and last of all four to six free carpels in the centre. A

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[2] I have recently received some preparations of *Hydrocleis nymphoides* from Prof. Karl Suessenguth of München and I intend to clear this point, as well as a few others, at an early date.

study of the organogeny (see Figs. 1–4) shows that the various parts of the flower develop in the usual acropetal succession.

The carpels arise as little protuberances on the receptacle and are at first quite free from one another throughout their entire lengths (Figs. 3 and 4). In slightly older flowers they are fused at the base (Fig. 5) but remain free throughout the greater part of the length (Figs. 6 and 7) presenting a horse-shoe shaped appearance in a transverse section. At the time when the ovules are maturing into seeds, the fusion extends upwards and the inner margins of the carpels become coherent up to about $\frac{2}{3}$ of the distance (Figs. 8 and 9). The tips, however, still remain free (Fig. 10) and the stylar canal
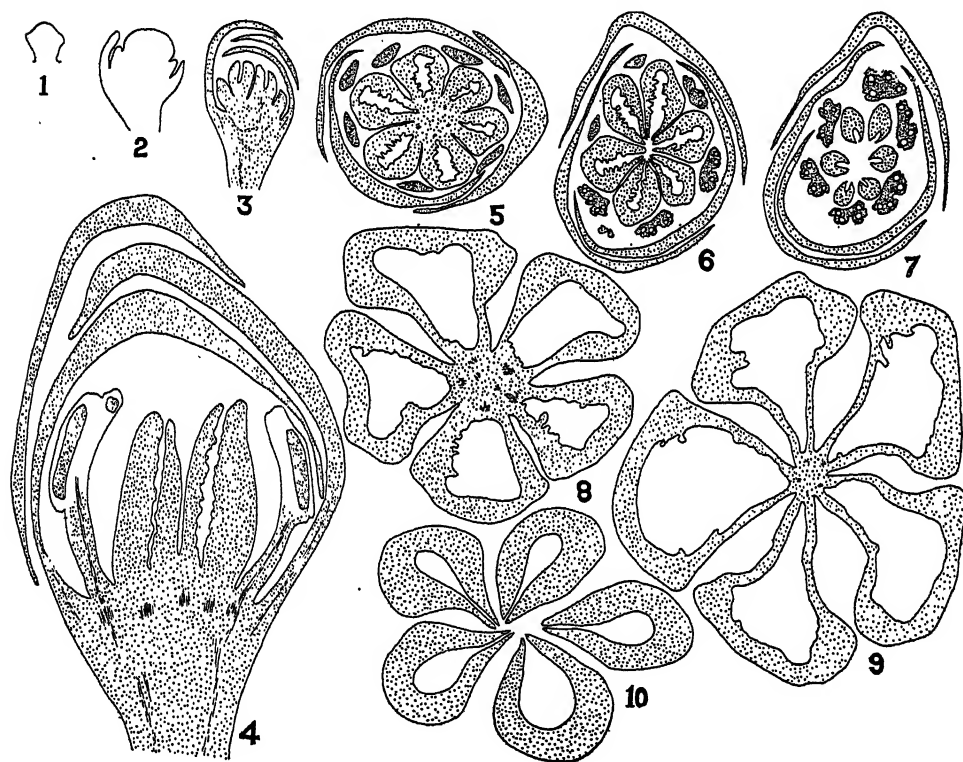


FIGS. 1–10. Fig. 1.—L.S. very young flower. $\times$ 37. Fig. 2.—Later stage showing the perianth and staminal protuberances. $\times$ 37. Fig. 3.—Still later stage showing perianth, stamens and two young carpels. $\times$ 37. Fig. 4.—Older flower, the sporogenous tissue has been delimited in the anthers and the ovules just beginning to develop on the inner surface of the carpels. $\times$ 37. Figs. 5–7.—T.S. young flower at the base, middle and top respectively (the sepals were removed before fixation and are therefore not seen in the figures). $\times$ 16. Figs. 8–10.—T.S. at base, middle and top regions respectively of a pentacarpellary pistil of an older flower (just after fertilisation; the ovules have been omitted). $\times$ 16.

of each carpel opens out through the stigma, establishing a direct communication with the atmosphere. More will be said of this under the section 'Pollination'. It is to be noted that the carpellary edges meet but never become completely coherent in the region of the stylar canal. The ovules appear on the entire inner surface of the ovary except the dorsal and ventral sutures and the base.

Troll (1932) has recently described the development of the gynæcium in *Limnocharis* and Eber (1934) has done the same in *Butomus* and *Hydrocleis*. The last two plants are essentially similar to *Butomopsis*, but *Limnocharis* is slightly different. In earlier stages it is comparable to *Alisma* and *Damasonium* and the 14–20 carpels arise from the periphery of the receptacle and not from the centre as in the other three genera. The carpels and the floral axis grow together for some time although towards the close of the development the former outgrow the latter. This results in a "pseudo-syncarpous[3] gynæcium" since the carpels are not united with one another except through the tissue of the floral axis ; at the top they are always free.

### Early Development of the Anther.

A young anther is four-lobed as usual and a group of hypodermal archesporial cells becomes recognisable in each corner. Periclinal divisions in the outer part cut off a primary parietal layer. This divides again to form two layers of which the outer becomes the endothecium, and the inner gives rise to an ephemeral middle layer and the tapetum (Fig. 11). Holmgren (1913, p. 60, footnote) writes that in *Butomus umbellatus* the tapetum originates from the sporogenous tissue, as in *Ranunculus* (Coulter, 1898) and *Lemna* (Caldwell, 1899). It may be mentioned here that at least in *Ranunculus sceleratus* (Singh, 1936) the tapetum is formed from the primary parietal layer in the usual way and the same is the case in *Wolffia arrhiza* (Gupta, 1935/36) a recently investigated member of the *Lemnaceæ*. This condition is so common in angiosperms that any claim for a sporogenous origin of the tapetum will have to be strongly supported before it can be accepted.

The endothecium acquires the usual fibrous thickenings at maturity. The middle layer begins to degenerate when the nuclei of the microspore mother cells are in the prophase of the heterotypic division and is soon crushed out of shape, but its remains may be seen even after the formation of the microspores (Fig. 12). The fate of the tapetum will be described a little later.

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[3] The actual term used by Eber (1934, p. 277) is "falsches cœnocarpes Gynæceum".
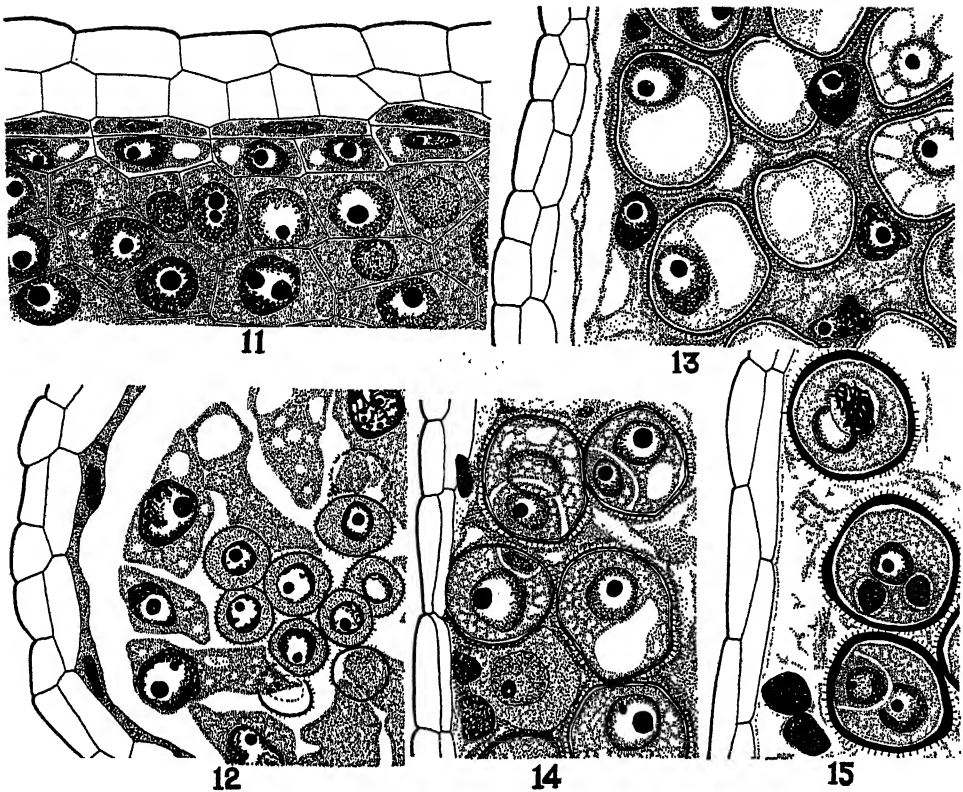
FIGS. 11–15.— ✕ 750. Fig. 11.—Part of an anther lobe showing microspore mother cells, tapetum, a middle layer, endothecium and epidermis. Fig. 12.—Same, later stage showing young microspores and beginning of periplasmodium formation; the middle layer is disintegrating. Figs. 13–14.—Uni- and bi-nucleate pollen grains imbedded in tapetal periplasmodium. Fig. 15.—Part of anther lobe with three pollen grains, lowest with tube and generative cells uppermost with generative cell in division; the central is three-celled. Only traces of the periplasmodium are left.

## Formation of Microspores.

When the microspore mother cells are preparing for the reduction divisions, their cytoplasm shrinks from the walls and rounds up, while a special wall is secreted between the original mother cell wall and the cytoplasm (Fig. 51). The original mother cell wall retains its former shape for a long time, except for a little rounding off at the corners. It disorganises only after the microspore tetrads have been formed (Fig. 58).

The reduction divisions are successive. During the early telophase of the heterotypic division the spindle fibres thicken in the equatorial region of the sp'ndle (Fig. 52) and ultimately a cell-plate is laid down which separates

the two daughter nuclei (Fig. 53). Immediately after the division is completed, the special wall appears between the two cells and becomes continuous with the special wall along the periphery (Fig. 54). During the homotypic division the two spindles may either lie parallel to each other, or at right angles or even in the same row. Thus the resulting microspore tetrads have various forms:—tetrahedral (Fig. 55), T-shaped (Fig. 56), linear (Fig. 57) or isobilateral (Fig. 58); of these the last is the commonest. *Typha latifolia* is a well-known case where all these arrangements are found (Wodehouse, 1935; p. 297). T-shaped tetrads of microspores are occasionally seen in *Aristolochia clematitis* (Samuelsson, 1914). A linear arrangement is common in the Asclepiads, but in the order Helobiales it has so far been reported only in *Ottelia alismoides* (Narasimha Murthy, 1935/36). Immediately after the formation of the four daughter cells the same material which forms the special wall, makes its appearance in between each of the young microspores in a tetrad, so that they lie imbedded in a homogeneously staining matrix (Figs. 55 and 56), which is probably secreted by the cytoplasm in the same way as shown by Gates (1924) in *Lathrea*. In the further development of the microspores this substance is absorbed first; the original mother cell wall persists a little longer (Fig. 57) and on its final disorganisation (Fig. 58) the microspores are set free.

*Tapetum.*—The tapetal cells remain uni-nucleate and their nuclei take a very dense stain in comparison to the nuclei of the microspore mother cells (Fig. 51). During the course of the reduction divisions, the tapetal cells loose their walls and their protoplasts become vacuolate (Fig. 51). At the time the microspores separate and round up, they begin to project inside the anther loculus (Fig. 12). Here they fuse irregularly and the microspores become imbedded in a tapetal periplasmodium (Figs. 13 and 14). The tapetal nuclei now become even larger than before and can be distinguished as deeply staining structures in between the pollen grains. The periplasmodium persists for a fairly long time and its remains can be distinguished even at the time the pollen grains have become three-nucleate (Fig. 15). A periplasmodium formation has also been described in this family in *Butomus umbellatus* (Tischler, 1915; Clausen, 1927) and *Limnocharis humboldti* (Clausen, 1927).

*Male Gametophyte.*

The microspore nucleus leaves its central position and comes to lie near the wall (Fig. 59) before division. The tube and generative nuclei are at first separated by a delicate membrane (Figs. 14 and 15), but this soon disorganises and the generative nucleus, which is easily distinguishable by its deeper stain and the surrounding sheath of cytoplasm, moves towards the

centre of the pollen grain close to the tube nucleus (Fig. 60).   One pollen grain was found to have developed a pouch-like outgrowth on one side and the generative cell was situated inside this protuberance (Fig. 61).

The two sperm cells formed by the division of the generative cell (Fig. 15) are spherical in the beginning (Fig. 15), but soon acquire a more oval outline (Fig. 62), sometimes becoming lenticular (Figs. 34 and 39).   They are always surrounded by a lightly staining area of cytoplasm which is sharply marked off from the general cytoplasm of the pollen grain (Figs. 15 and 62 ; *cf.*, *Portulaca oleracea*, Cooper, 1935).   In older pollen grains the tube nucleus has a famished appearance and takes a very light stain with hæmatoxylin, and sometimes all the three nuclei of the pollen grain degenerate (Fig. 63). In such cases the male nuclei are specially elongated and the cytoplasmic sheath which surrounds them is no longer distinguishable.   The germ pores are usually three in number (Figs. 65 and 66), but sometimes there may be as many as four or five.

### *The Ovule.*

As pointed out previously there are numerous ovules arising all over the inner surface of the ovary wall.   As in other members of the family, they have two integuments and are completely anatropous when mature (Fig. 31).   Both of the integuments are two-layered and remain separate from each other and also from the nucellus throughout their entire lengths (Fig. 31).   The micropyle is formed entirely by the inner integument and the outer does not develop very far on the side of the funiculus.   The embryo sac is at first quite straight but immediately after fertilisation it begins to elongate at the chalazal end and curves over, finally becoming absolutely doubled up and assuming a U-shaped appearance (Figs. 40, 41 and 44).

### *The Archesporium and First Division of the Megaspore Mother Cell.*

Normally a single hypodermal archesporial cell differentiates in the young nucellus (Fig. 16, right ovule), but sometimes there are two (Fig. 16, left ovule).   More than one archesporial cell is also known to occur in *Butomus umbellatus* (Holmgren, 1913).

As can be seen from Figs. 17 and 18, the archesporial cell functions directly as the megaspore mother cell without cutting off any wall cell.   The nucellar epidermis, however, often divides here and there and becomes two layered (Fig. 22), which may give the false impression of the cutting off of a wall cell.   Hall (1902) says that in *Limnocharis* a tapetal cell is cut off and pushed towards the apex where it disappears in later stages.   This seems to be a misinterpretation and we shall return to this question a little later.

B. M. Johri
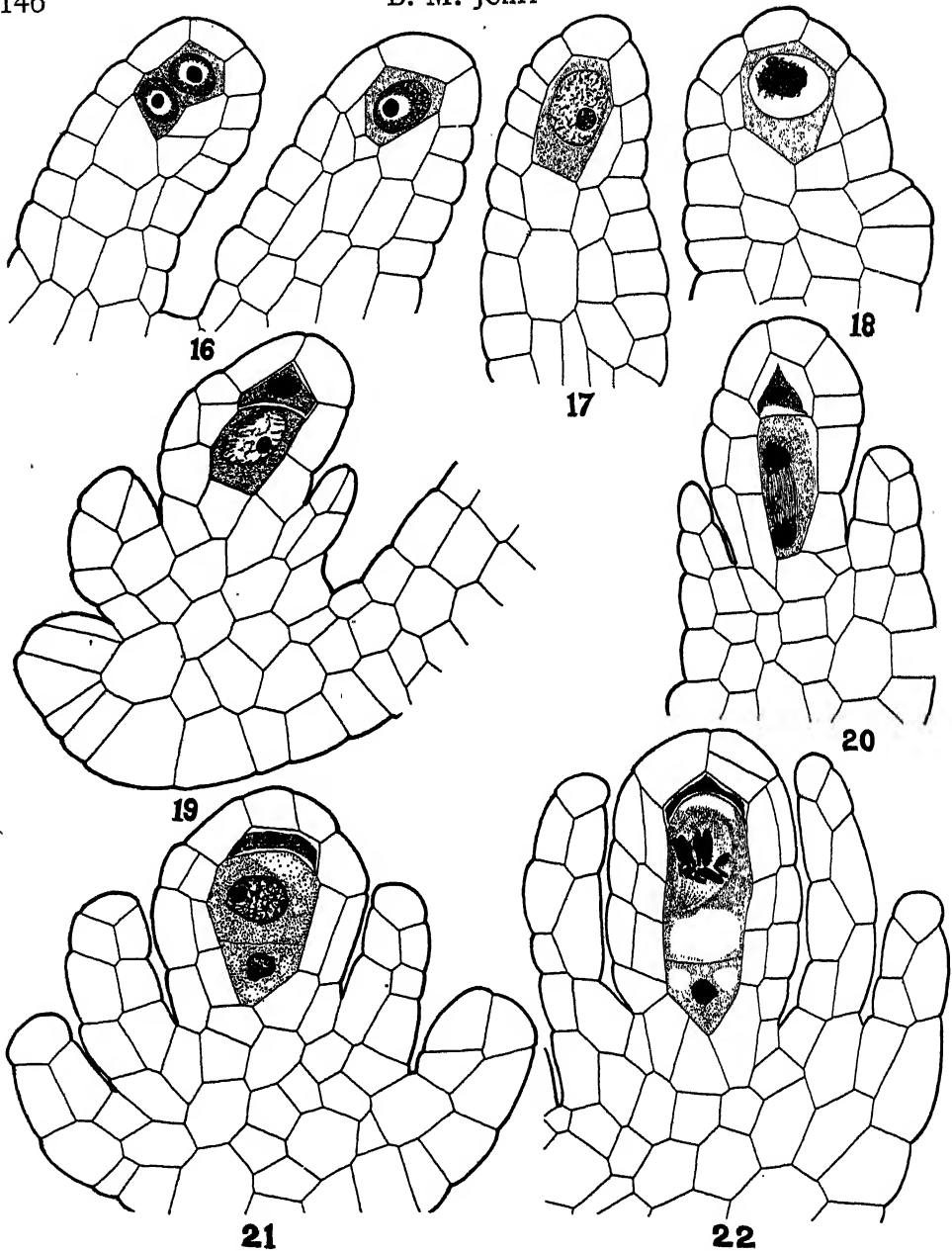


FIGS. 16–22.— × 750. Fig. 16.—Two adjacent ovules in a carpel; there is a single hypodermal archesporial cell in the one towards the right; two in the left. Fig. 17.—Nucellus with megaspore mother cell preparing for the heterotypic division. Fig. 18.— Megaspore mother cell in synizesis. Fig. 19.—Two daughter cells formed after the heterotypic division. Fig. 20.—Upper dyad cell degenerating, lower in division. Fig. 21.—Two-nucleate embryo sac; the primary chalazal nucleus is cut off by means of a delicate membrane. Fig. 22.—The primary micropylar nucleus in division; the primary chalazal nucleus is in process of degeneration.

Schaffner (1896) also made a similar mistake and wrote that a wall cell is cut off in *Alisma plantago* but the reinvestigation by Dahlgren (1928) proved the inaccuracy of the former interpretation. *Butomus umbellatus* (Holmgren, 1913 ; p. 64) seems to be the only member of the family in which a wall cell is really cut off, but even here the primary archesporial cell sometimes functions directly as the megaspore mother cell. Several other members of the allied family *Alismaceæ*, besides *Alisma* which has already been cited above, have been recently investigated but a wall cell has not been seen in any of them.

The megaspore mother cell divides to form two cells of which the upper is smaller than the lower from the very beginning (Fig. 19) and soon disorganises to form a densely staining cap which can be recognised for a long time on the top of the developing embryo sac (Figs. 22, 24 and 29). The lower dyad cell develops into an embryo sac without the formation of tetrad of four megaspores. Thus the development is essentially of the "Scilla-type" though partly modified as described below.

*Embryo Sac.*

As a result of the first division of the lower dyad cell (Fig. 20), the primary micropylar and the primary chalazal nuclei are formed as usual. The latter is, however, very small and is at once cut off from the rest of the embryo sac by a delicate membraneous partition (Fig. 21). This cell does not divide any further and the nucleus begins to degenerate almost immediately after it is formed, but it remains recognisable for a long time in the embryo sac (*cf.* Figs. 21–31, 40–42 and 44).
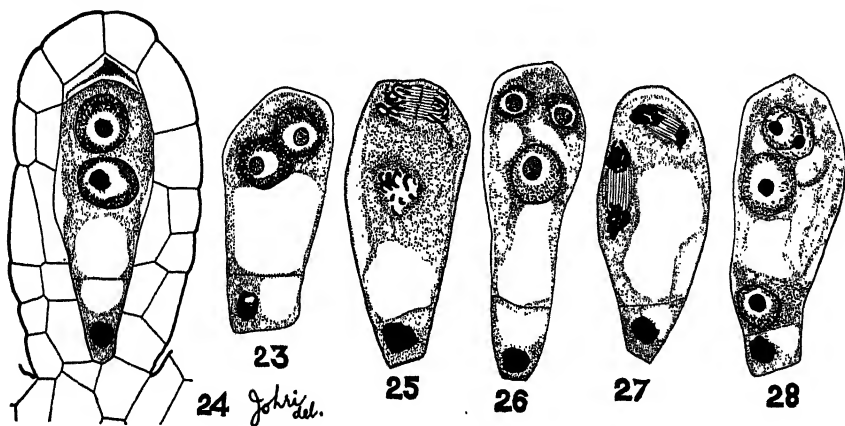


FIGS. 23–28.— $\times$ 750. Fig. 23.—Embryo sac with two nuclei at the micropylar end and the undivided chalazal nucleus. Fig. 24.—Same stage, but embryo sac is slightly larger than usual. Fig. 25.—The lower of the two daughter nuclei in the micropylar end has lagged behind in division. Fig. 26.—One of the micropylar nuclei

has divided to form two daughter nuclei, while the other has so far failed to divide. Fig. 27.—Both the micropylar nuclei undergoing division. Fig. 28.—Abnormal embryo sac, in which one of the four micropylar nuclei has migrated to the chalazal end.

The primary micropylar nucleus divides (Fig. 22) to produce two nuclei (Figs. 23 and 24) and usually both of these divide again simultaneously (Fig. 27) to form four (Fig. 29). Three of these organise themselves into a normal egg apparatus with two synergids and an egg; while the fourth remains free as a polar nucleus (Fig. 30). The lower polar nucleus is entirely absent. The sequence of development here, is thus very similar to that found in *Echinodorus macrophyllus* (Dahlgren, 1934).
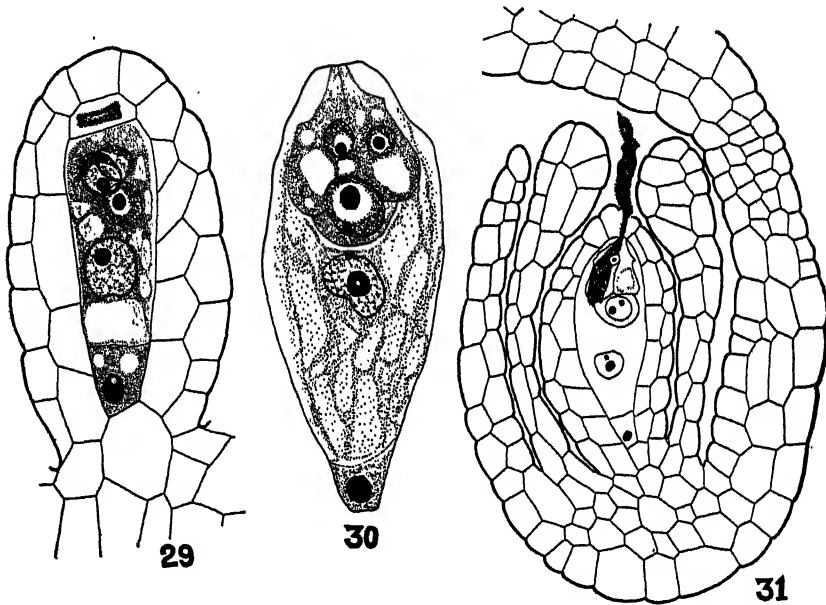


FIGS. 29–31. Fig. 29.—Embryo sac with four nuclei in the micropylar end and the undivided primary chalazal nucleus in the antipodal end. The remains of the upper dyad are still visible at the top of the embryo sac. × 750. Fig. 30.—A mature embryo-sac with hooked synergids, egg, upper polar nucleus and an antipodal cell. × 750. Fig. 31.—L.S. of an ovule at the time of fertilisation showing a pollen tube entering the embryo sac. The latter has been drawn at a higher magnification in Fig. 68. × 375.

Fig. 30 shows a mature embryo sac. The synergids are hooked and have a filiform apparatus at the upper end. They do not persist after fertilisation and by the time a three- to five-celled proembryo is formed they entirely disappear (Fig. 41). In contrast to this is the condition met with in *Limnophyton* (Johri, 1935a) and *Sagittaria guayanensis* (Johri, 1935/36) where one

synergid persists for a long time after fertilisation. The egg projects lower down than the synergids. The single polar nucleus is the biggest of all the nuclei of the embryo sac (Figs. 29 and 30). As mentioned earlier a second polar nucleus is never formed and the degenerated nucleus cut off by a membrane at the chalazal end of the embryo sac represents the only antipodal cell.
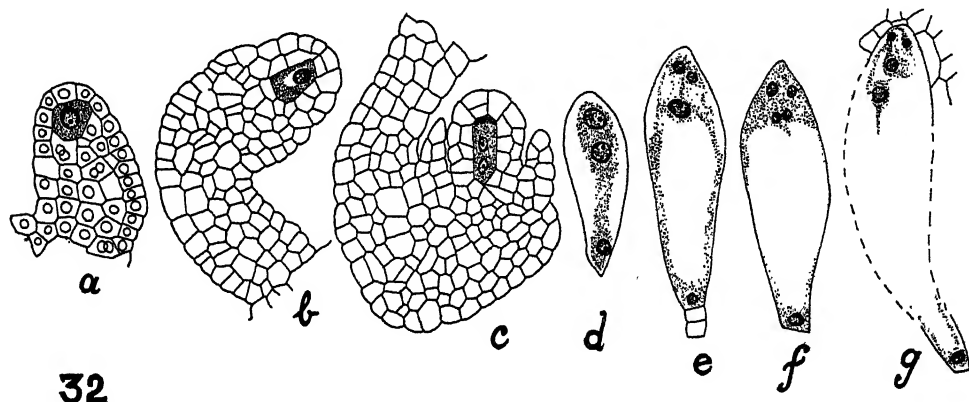


FIG. 32 *a–g*.—Development of the embryo sac in *Limnocharis emarginata*. All figures redrawn from Hall (1902) and reduced to 2/3 in reproduction. For explanation, see text.

Here, we might return to Hall's (1902) work on *Limnocharis emarginata*. I have redrawn his Figs. 2–8 and am reproducing them here for the sake of comparison (see Fig. 32, *a–g*). According to Hall's interpretation the primary archesporial cell (Figs. 32*a* and 32*b*) divides into two cells of which the upper is a tapetal cell (Fig. 32*c*) and the lower is the megaspore mother cell. The latter gives rise to a five-nucleate embryo sac (Fig. 32, *c–g*) which must be considered to be a reduced "Lilium-type," if Hall's interpretations are correct. But the similarity between Hall's figures of *Limnocharis*, Dahlgren's figures of *Echinodorus* and mine of *Butomopsis* is so close that they must be regarded as belonging to the same type. It seems clear that although Hall must be given the credit of accurately representing in his figures what he actually saw in the preparations, his conclusions were probably incorrect. What he regards as a tapetal cell and megaspore mother cell are really the *two cells formed after the heterotypic division of the hypodermal megaspore mother cell* and the lower of these proceeds to form the embryo sac as in other plants which are classed under the "Scilla-type". Nitzschke's (1914) report of the occurrence of six- and eight-nucleate embryo sacs in this plant is of interest since it proves that the same type of variation, which occurs in the ALISMACEÆ (Johri, 1935*a*, 1934/35 and 1935/36), can be found here also.

Among other angiosperms, the condition found in *Butomopsis* is parallel-ed to a certain extent in *Nipa fruticans* (Radermacher, 1925), but here the chalazal nucleus moves up and fuses with the upper polar nucleus. A better comparison is afforded by *Lawia zeylanica* (Magnus, 1913) and some other plants of the *Podostemaceæ* (see Schnarf, 1927; pp. 195–196), where also the megaspore mother cell divides into two daughter cells of which the lower develops into an embryo sac. The first division produces two nuclei of which the lower becomes separated by an ephemeral wall. According to Went (1910), this is a persistent antipodal nucleus, while Palm (1915) prefers to call it a megaspore nucleus. The upper nucleus divides twice and the four nuclei thus produced give rise to a normal egg apparatus and the upper polar nucleus. The lower polar nucleus is absent but Magnus (1913) reports that sometimes the antipodal nucleus fuses with the upper polar nucleus.

Palm (1915) is of the opinion that the type of development found in *Lawia* should be regarded as a modification of the "*Oenothera*-type". This can be correct only if the single antipodal nucleus is not regarded as a consti-tuent of the embryo sac. It appears to me more reasonable (see also Went, 1910) to regard this as a modification of the "Scilla-type," in which the chalazal part of the embryo sac has become greatly reduced due to the absence of divisions of the primary chalazal nucleus.

Certain variations may now be noted regarding the development of the embryo sac in *Butomopsis*. In one case, it was seen that after the division of the primary micropylar nucleus, one of the two daughter nuclei divided earlier than the other (Fig. 25), and in another embryo sac there were only three nuclei instead of four in the upper end (Fig. 26; compare this which Hall's Fig. 6, reproduced here as 32e).

Usually there is only a single degenerated nucleus at the narrower end of the embryo sac but in one case an additional nucleus was seen at the chalazal end (Fig. 28). This nucleus evidently belongs to the group of four micropylar nuclei but has somehow migrated to the lower end of the embryo sac.

### Pollination.

Some striking phenomena were noticed in this connection and I alluded to them briefly in a preliminary note published in *Nature* in August, 1935b. Usually, the pollen grains germinate on the stigma as in other angiosperms and the pollen tubes pass down the walls of the hollow stylar canal to the ovary, but in one case I noticed a row of six pollen grains *within the stylar canal itself* and five of these could be seen in a single section (Figs. 33 and 34). In another carpel belonging to the same flower a group of eight pollen grains

was found caught up in the stylar canal[4] (Fig. 35) and in a third there was a
pollen grain at the junction of the stigma and the style (Fig. 36).   In another
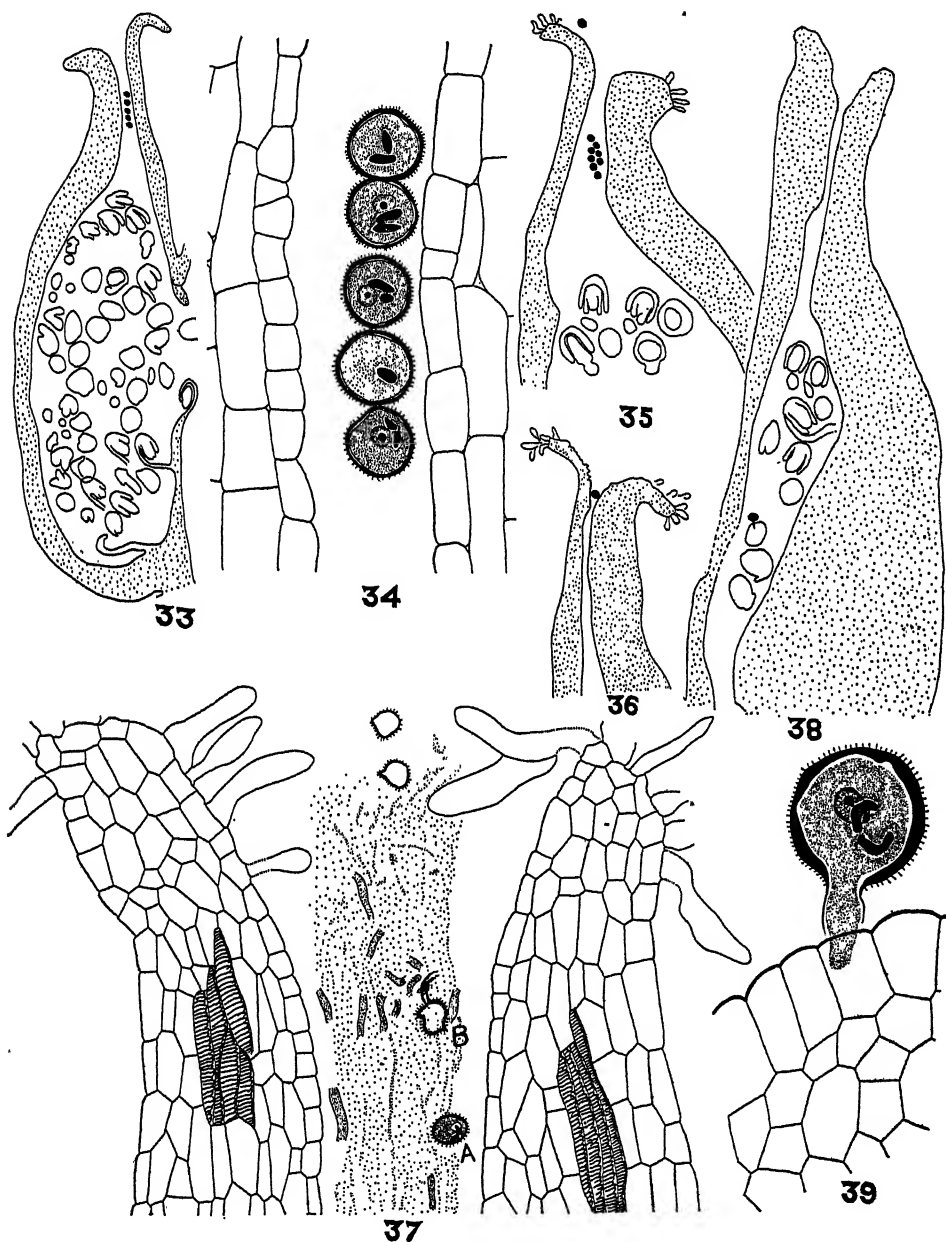


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FIGS. 33–39.—Fig. 33.—L.S. of a carpel showing pollen grains in the stylar canal. $\times$ 25. Fig. 34.—Same, upper part of the stylar canal enlarged to show the structure of the pollen grains. $\times$ 375. Fig. 35.—Upper part of a carpel showing a group of eight pollen grains in the stylar canal. $\times$ 37. Fig. 36.—Same, one pollen grain lodged at the tip of the stylar canal. $\times$ 37. Fig. 37.—Upper end of a carpel showing the stylar canal with irregularity cut pollen tubes and two pollen grains; the one at 'B' has put out a germ tube. $\times$ 162. Fig. 38.—L.S. of an ovary (the section has passed near the surface) showing a pollen grain germinating directly on an ovule. $\times$ 25. Fig. 39.—The pollen grain in the last figure is enlarged to show nuclear details. $\times$ 1125.

flower there were two pollen grains in a stylar canal, one of which had germinated *in situ*, although the pollen tube could not be traced very far (Fig. 37 'B'). In eight other carpels belonging to four different flowers, *pollen grains were found inside the ovary and in one case a pollen grain had germinated on the surface of an ovule*, which was unfortunately cut obliquely (Figs. 38 and 39). A critical study of the size and nuclear contents of the pollen grains referred to above revealed that they were not foreign spores (Sahni, 1935/36) but belonged to the same species.

The question naturally arises as to how the pollen grains reached the stylar canal and the ovary in the above cases. As remarked by Prof. Sahni (1935/36), "it seems impossible to explain the entry of these spores, even into the upper part of the canal, except on the assumption that they were drawn in by some sort of suction mechanism like that of the 'stigmatic drop'[5] of gymnosperms, the stylar canal functioning like a micropyle".

The condition described here has not been recorded previously in any other living angiosperm, but some comparison is afforded by a new member of the Caytoniales, named as *Caytonia Thomasi* by Prof. Harris (1933). This differs from the previously described *C. Sewardi* (Thomas, 1925) in having an essentially gymnospermous type of pollination, for here Harris could find pollen grains in the micropyles of many ovules. He believes that the carpel was open at the time of pollination and that the widely open micropyles of the contained ovules were connected to the stigmatic opening by means of narrow canals, through which the pollen grains were drawn in by some suction mechanism. This type of pollination is evidently quite different from that met with in angiosperms, where pollen grains germinate on the stigma and the pollen tubes have to pass through the whole of the stylar tissue before reaching the ovary.

Prof. Harris (1933, p. 108) also wrote a very suggestive paragraph which I am quoting here in full : "There is virtually no evidence to show what was

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[5] The usual term, "Pollination drop", is better since there is no stigma in gymnosperms,

the pollination mechanism of primitive Angiosperms (such variations as occur in the stigma, *e.g.*, in *Zannichellia* or *Reseda*, being no doubt secondary), but it seems by no means unlikely that it may have been similar to what is postulated for *Caytonia*. Possibly the style was originally an open canal along which the pollen was conveyed (on a drop of fluid) to the ovules ; a later stage would be the germination of the pollen grain before it reached the micropyle, at first no doubt at the bottom of the stylar canal, then at its middle and then at its top. The final change to occur—the closure of the stigma—makes it impossible for the pollen to pass down the stylar canal. "

The condition described in *Butomopsis* is almost exactly what Harris would expect in his primitive angiospermous type and the fact that the *Butomoceæ* is really one of the most primitive families of the angiosperms, gives added importance to the phenomenon I have come across. It might be mentioned that very recently I have also seen a pollen grain in the ovary of *Butomus umbellatus*.

It is not possible to pass on to the next topic without making a reference to the interesting genus *Gnetum*, which has been so carefully investigated by Thompson (1916). This shows many angiospermous features and according to some botanists it actually occupies an intermediate position between the remaining gymnosperms and the angiosperms. The inner envelope is here very similar to a stylar canal both in appearance and function. The usual pollination drop found in gymnosperms exudes out at the top and the pollen grains are drawn below to the nucellus. Not all of them pass down to the bottom, however. Prof. Thompson finds that many germinate even in the "style" at a considerable distance away from the nucellus, and this is a point which appears to the present writer to be of considerable importance. If further anatomical evidence could be brought forward and it could be proved conclusively that the inner envelope is really a stylar canal and not an integument, it would take us a step forward in the solution of the major problem of the origin of angiosperms. It may, of course, be a case of parallel development, but it would still give a new orientation to our present ideas of the problem.

### Pollen Tube.

In two flowers the pollen grains had germinated *in situ* and this provided a good series of stages in the development of the pollen tubes. Fig. 64 shows that the pollen tube need not always arise from the end close to the tube nucleus but sometimes it may come out on the opposite side. It may even attain some length before the tube nucleus enters inside it (Fig. 65).

The male gametes retain their cytoplasmic sheaths and pass along the tube as definite male cells (Fig. 66). In later stages the tube nucleus becomes

amœboid and takes a very dark stain.    Fig. 67 shows a part of a pollen tube which was just ready to enter an ovule.    It can be seen that  even here the male gametes are distinct cells and not merely nuclei.    After the pollen tube had entered the embryo sac, the sperm cells take the lead leaving the tube nucleus behind (Fig. 68).    Even at this stage the lightly staining cytoplasm of the male gametes remains distinguishable.

Wylie (1923) traced the male gametes as distinct cells in *Vallisneria spiralis* from the time of their formation in the pollen grains up to  their discharge in the embryo sac and Finn (1925) found the same in *Asclepias cornuti*.    With suitable fixation and sharp staining it is likely that many angiosperms will show *male cells* instead of *nuclei* in the pollen grains as well as pollen tubes (also see Finn, 1935).    It is possible that they remain so even up to the time of  fusion with the egg and the polar nuclei but this is very difficult to demonstrate due to the difficulty of obtaining a sufficiently good preparation of this stage.

*Fertilisation.*

The pollen grains usually germinate on the stigma and the pollen tubes pass through the stylar canal and then the ovary, finally reaching the ovules. Fig. 31 shows the course of a pollen tube entering an embryo sac through the broad micropyle.    In its passage through the nucellus it becomes rather narrow, but immediately on reaching the embryo sac it again swells.    During its entry into the embryo sac one of the synergids is always disorganised and the second disappears a little later.    Only the male cells are  discharged into the embryo sac, the tube  nucleus remaining behind.    One sperm nucleus fuses with the egg and the other with the single polar nucleus.    In Fig. 69 one of the sperm nuclei is still attached to the egg nucleus while the other is in advanced stage of fusion with the polar nucleus.    This would indicate that syngamy occurs a little later than the " fertilisation " of the polar nucleus.

Although the male cells retain their identity up to the time they are in the pollen tube, I could not succeed in observing the penetration of the male cytoplasm into the egg.    The inclusion of this cytoplasm in the zygote, if proven, would have important implications when considered from a gene-tical view-point.    Nevertheless, *Butomopsis* appears to me to be a more suitable object for a study of the male cells than any other plant I have come across and if I am able to get together a sufficient number of flowers of the right stage, I shall try to use more precise methods of staining and return to this interesting topic at a later date.

Often two degenerated dark staining bodies were seen in pollen tubes which had discharged the male gametes (Figs. 40 and 69.)  They have been

called "*X-bodies*" by several authors who have interpreted them variously as the nuclei of the synergids, the degenerated cytoplasmic remains of the male cells, or as the tube nucleus (Artschwager and Starrett, 1933; p. 832; also *cf.* Dahlgren, 1927; p. 175).

### Endosperm and Embryo.

The mode of endosperm formation is of the type so common in the Helobiales. The primary endosperm nucleus travels down to the narrower end of the embryo sac (Fig. 40) and here it divides to produce two daughter nuclei separated by a wall. The nucleus of the upper chamber travels to the middle of the embryo sac and undergoes many free nuclear divisions, but the nucleus of the smaller chalazal chamber either remains undivided (Figs. 41 and 44) or only divides once (Fig. 42). Hall (1902) and Holmgren (1913) have reported a similar condition in *Limnocharis* and *Butomus* respectively.
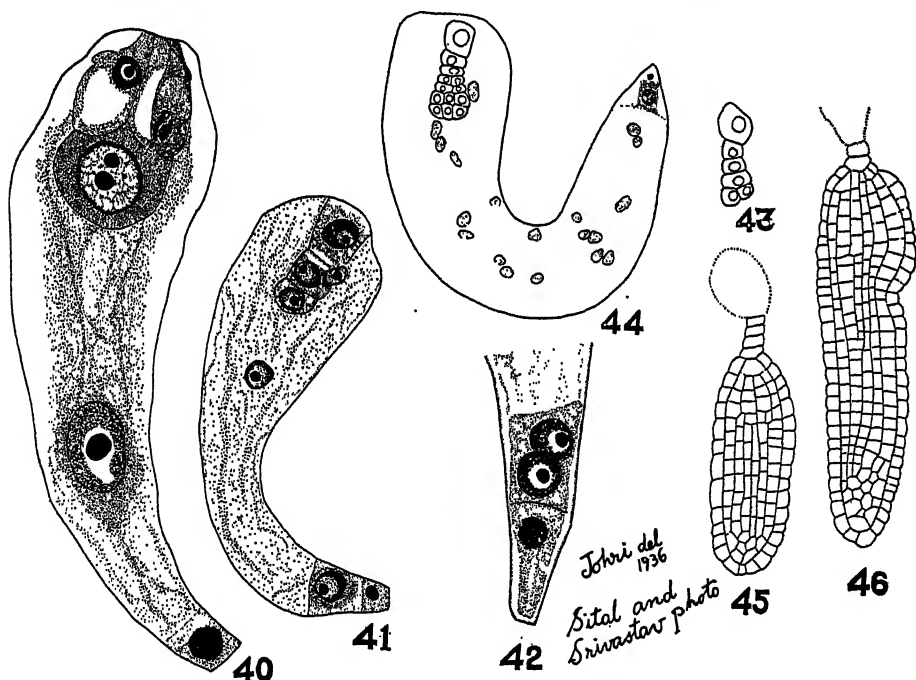


FIGS. 40–46. Fig. 40—Fertilised embryo sac. $\times$ 750. Fig. 41.—Embryo sac with a three-celled proembryo. The synergids have disappeared and the endosperm is of the Helobiales type; the nucleus in the chalazal chamber is undivided. $\times$ 325. Fig. 42.—Chalazal part of an embryo sac showing two endosperm nuclei in the chalazal chamber and the single antipodal nucleus still persisting at the base. $\times$ 750. Fig. 43.—A young proembryo of five cells, with the terminal cell divided vertically. $\times$ 162. Fig. 44.—Embryo sac with an older embryo; there are many free endosperm nuclei in the micropylar chamber and undivided nucleus in the chalazal chamber. $\times$ 162. Figs. 45 and 46.—Older embryos. $\times$ 162.

The first division of the oospore is transverse and it seems to take place simultaneouly with or shortly after the division of the primary endosperm nucleus. · The two-celled pro-embryo consists of a large basal cell and a small terminal cell. The development of the embryo (Figs. 41, 43 and 44) is similar to that of *Limnophyton* (Johri, 1935a) and *Sagittaria guayanensis* (Johri, 1935/36). Figs. 45 and 46 show the oldest embryos observed.
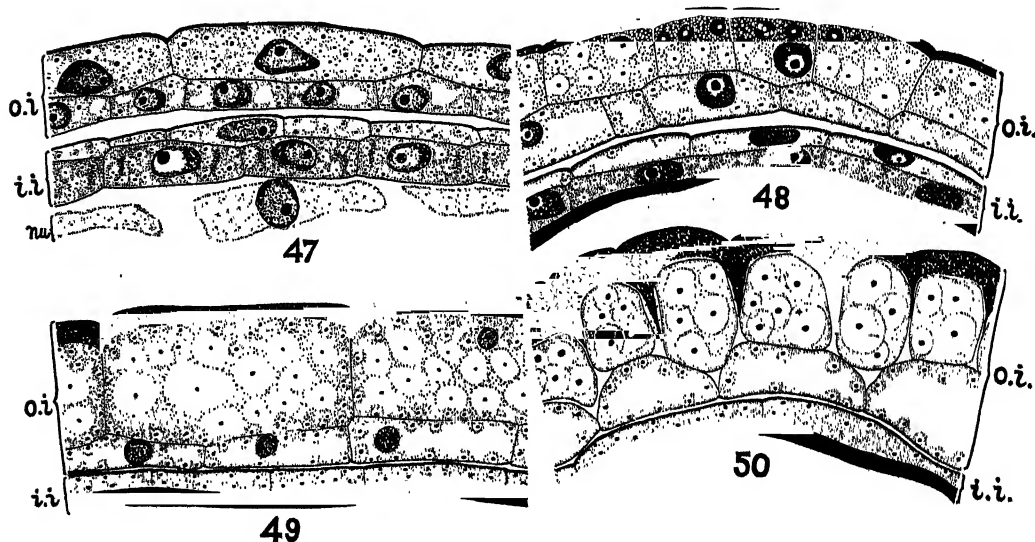





FIGS. 47–50.—✕ 750. Drawn to show the differentiation of the seed-coat. For explanation, see text. (*o.i.*, Outer integument; *i.i.*, inner integument; *nu*, nucellar cells.)

*Seed-coat.*—After fertilisation has been accomplished in the embryo sac the nucellus begins to disorganise while the inner layer of the inner integument becomes richly protoplasmic and functions as an integumentary tapetum (Fig. 47). During the further growth of the embryo, the outer layer of the inner integument is crushed and completely absorbed, while the remaining three layers store large quantities of starch. The innermost and outermost of these (specially the latter) become heavily cutinised in the seed (Figs. 48–50).

## Discussion.

The *Alismaceæ* and the *Butomaceæ* are both closely allied families belonging to the order Helobiales. Hooker (1894) has actually included members of both under a single name (*Alismaceæ*) and recently Rendle (1930) has done the same. On the other hand, Hutchinson (1934) gives them the rank of separate orders :—the *Butomales* and the *Alismatales*. So far as the embryology of the two families is concerned it would appear that they are closely related to each other.

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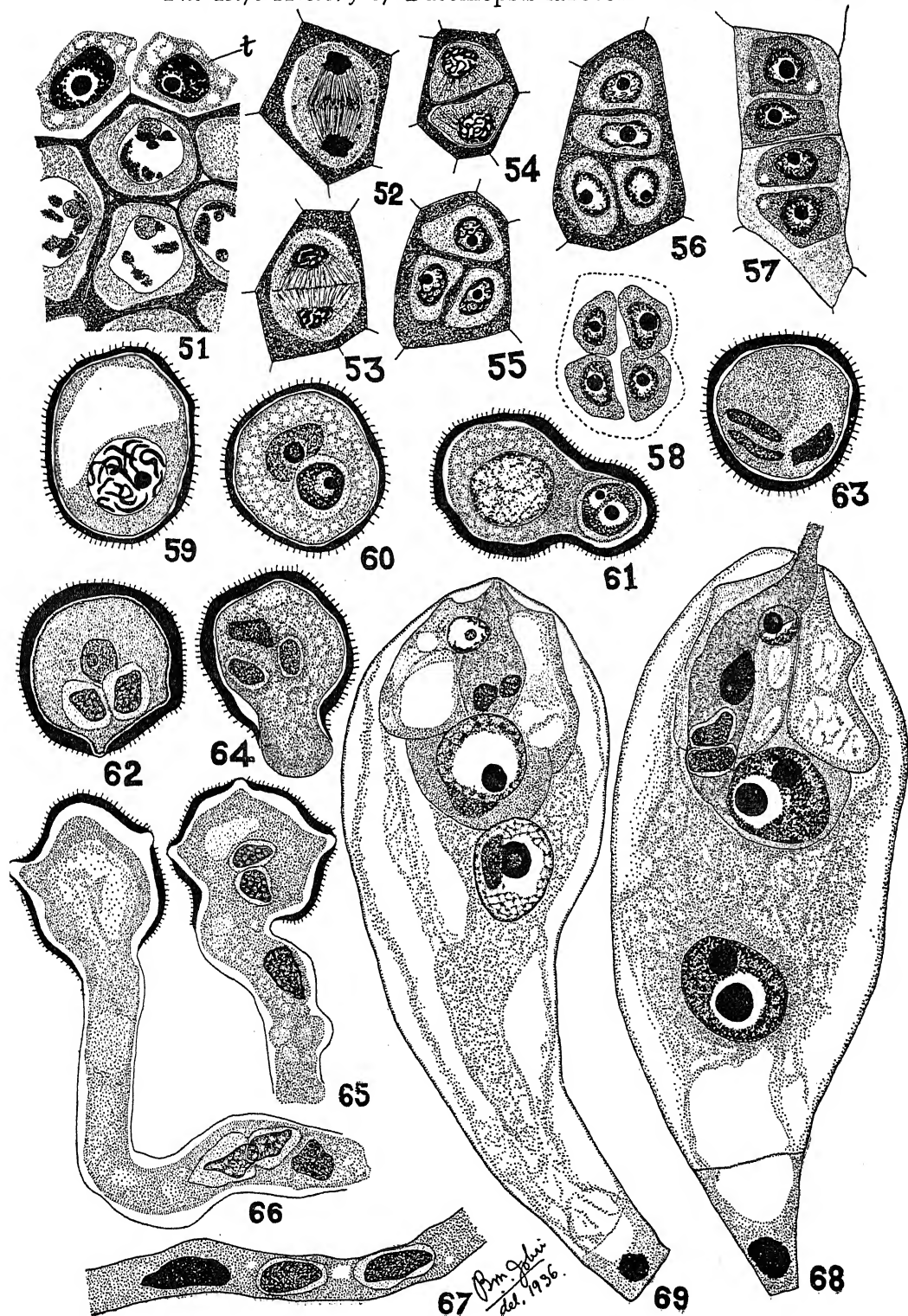
Fig.  51.—Part of an anther lobe, showing two tapetal (t) cells and a number of microspore
         mother cells.  $\times$ 1000.
Fig.  52.—Microspore mother cell; early telophase of first reduction division.  The special
         wall is quite prominent.  $\times$ 1000.
Fig.  53.—Same, late telophase; a cell plate has been laid down between the two daughter
         nuclei.  $\times$ 1000.
Fig.  54.—Slightly older stage; the special wall has extended in between the two daughter
         cells.  $\times$ 1000.
Figs. 55–58.—Tetrads of microspores.  $\times$ 1000.
Fig.  59.—Uni-nucleate pollen grain.  $\times$ 1000.
Fig.  60.—Bi-nucleate pollen grain with the generative cell and tube nucleus.  $\times$ 1000.
Fig.  61.—An abnormally-shaped pollen grain of the same stage with the generative cell in
         the narrower end to the right.  $\times$ 1000.
Fig.  62.—Mature pollen grain with two sperm cells and tube nucleus.  $\times$ 1000.
Fig.  63.—A degenerating pollen grain.  $\times$ 1000.
Figs. 64–66.—Stages in germination of the pollen grain.  $\times$ 1000.
Fig.  67.—Part of a pollen tube, from inside an ovary, showing male cells and the tube
         nucleus.  $\times$ 1500.
Fig.  68.—Mature embryo sac, just before fertilization.  The pollen tube contains male cells
         and a deeply stained tube nucleus.  $\times$ 1500.
Fig.  69.—Embryo sac showing double fertilization.  $\times$ 1000.

The early development of the anther, the tapetal periplasmodium and the male gametophyte are essentially similar in nearly all the genera of *Alismaceæ* and *Butomaceae* investigated so far.  The pollen grains show definite male cells.

Usually a single hypodermal archesporial cell differentiates in the young nucellus.  A wall cell is never formed (except in *Butomus umbellatus*, Holmgren, 1913) and the archesporial cell functions directly as the megaspore mother cell.

In all the *Alismaceæ* and in two genera of the *Butomaceæ*, viz., *Limnocharis* and *Butomopsis*, the development of the embryo sac follows the "Scilla-type".  A tetrad of four megaspores occurs only in *Butomus*; it has also been reported in *Hydrocleis nymphoides* (Suessenguth, 1921) but this cannot be finally accepted until a reinvestigation has been made.

In both of these families there seems to be a tendency towards a reduction of the nuclear content of the chalazal end of the embryo sac so that a total of only six nuclei is obtained in the majority of cases.  The occurrence of seven- and eight-nucleate embryo sacs is an interesting variation and the five-nucleate embryo sacs, found in *Butomopsis*, *Limnocharis* (Hall, 1902) and *Echinodorus* (Dahlgren, 1934), represent the farthest limit of reduction so far discovered in these families.

Endosperm formation is of the Helobiales-type except in *Alisma plantago*, *Damasonium alisma* and *Elisma natans* (Dahlgren, 1928) where it is free

nuclear. Stages in the development of the embryo are similar in both the families.

Most of the above features (except the Scilla-type of embryo sac) are common with members of other families included under the order Helobiales. This, in my opinion, is a very natural assemblage. The chief difference between the *Alismaceæ* and *Butomaceæ* concerns the arrangement of the ovules. In the former they are few in number and are borne on a marginal placenta, while in the latter their number is indefinite and they are borne superficially on the inner walls of the ovary. It seems unnecessary on the basis of this character alone to erect separate orders for them. Eber (1934, p. 281) who has made a very thorough study of the carpellary structure and placentation in the Helobiales makes the following remark, " Vergleichende Betrachtungen jedoch werden beweisen, dass es sich bei den Alismataceen lediglich um einen abgewandelten, nicht aber um einen von den Butomaceen grundsätzlich verschiedenen Typus handelt ; somit wird auch die Stellung der Alismataceen und Butomaceen in eine gemeinsame Verwandtschafts-gruppe vom Standpunkt der Plazentation vollkommen gerechtfertigt sein.''

## Summary.

1. The floral parts originate in acropetal succession.

2. There is a hypodermal group of archesporial cells in each anther lobe. The endothecium, an ephemeral middle layer and the tapetum are formed in the usual manner.

3. The tapetal cells remain uni-nucleate. A true periplasmodium is formed which persists until the pollen grains attain maturity.

4. The reduction divisions are successive and the microspore tetrads are usually of the bilateral type but sometimes they may be tetrahedral, linear or even T-shaped. The pollen grains are three-nucleate at the time of shedding. The male gametes have a variable shape though commonly they are spindle-shaped at maturity and are always surrounded with a sheath of lightly staining cytoplasm and are thus recognisable as cells.

5. The male gametes were traced as cells throughout their course in the pollen tube.

6. The mature ovule is anatropous with the usual two integuments. The nucellar epidermis divides here and there and becomes two layered. The embryo sac curves after fertilisation and becomes U-shaped.

7. Usually a single hypodermal archesporial cell is distinguishable in the young nucellus but sometimes there may be two. No wall cell is cut off and the archesporial cell functions directly as the megaspore mother cell.

The latter divides and produces two cells of which the upper is smaller and soon degenerates while the lower develops into the embryo sac.

8.  The first division of the megaspore nucleus gives rise to two nuclei of which the chalazal is nearly always cut off by a delicate membrane and takes no further part in the development.

9.  The primary micropylar nucleus divides twice and out of the four nuclei thus formed, an egg-apparatus and an upper polar nucleus are organised. The degenerated primary chalazal nucleus represents the only antipodal cell. Some irregularities have been described in the development of the embryo sac.

10.  The pollination is quite normal as in other angiosperms but in a few cases pollen grains were discovered in the stylar canal and in one case a pollen grain had begun to germinate on an ovule inside the ovary.

11.  Syngamy occurs a little later than the " fertilisation " of the upper polar nucleus. The endosperm is of the Helobiales-type and the embryo is essentially similar to that of *Alisma*.

12.  From the embryological standpoint there is a close affinity between the *Alismaceæ* and *Butomaceæ* and their separation into different orders is thought to be unnecessary.

### *Acknowledgments.*

In the end it is my pleasant duty to thank Dr. P. Maheshwari for his kind help and guidance throughout the course of this work. I am specially indebted to him for critical suggestions in connection with the striking phenomenon of pollination observed in this plant. I am also thankful to Principal F. J. Fielden of the Agra College and Mr. D. C. Mandeville of the St. John's College, Agra, for their help in translating some German literature.

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# STUDIES ON THE MECHANISM OF BIOLOGICAL NITROGEN FIXATION.

## Part IV. Nitrogen Fixation by the Mixed Microflora of the Soil in Presence of the Acid Products of Anærobic Decomposition of Carbohydrates.

BY T. R. BHASKARAN, B.SC.

AND

V. SUBRAHMANYAN, D.SC., F.I.C.

*(From the Department of Biochemistry, Indian Institute of Science, Bangalore.)*

IT was shown in an earlier communication (Bhaskaran and Subrahmanyan, 1936) that nitrogen fixation by the mixed flora of the soil commences largely after the added sugar is fully decomposed. Evidence was also adduced to show that the residual organic matter, consisting chiefly of organic acids, is used in the fixation.

Under the ordinary conditions of the soil the major part of the added organic matter is converted into gases, chiefly carbon dioxide. Only a small part is converted into acids. Recent studies by Bhaskaran (1936[1]) have shown that if the organic matter is subjected to preliminary fermentation outside the field and under conditions of restricted air supply, gas production is reduced and the major part of the added organic matter is converted into acids chiefly, lactic, acetic, propionic and butyric. In view of these observations, it appeared probable that if the organic matter is applied to the soil after some preliminary fermentation, there will then be greater return of nitrogen for the carbon applied than would otherwise be the case.

*Experimental.*

*The effect of addition of large quantities of the mixed calcium salts to a mineral medium.*—The preliminary fermentation was conducted in narrow-necked culture flasks which were filled almost to the brim with mixtures of soil (200 g.) and sugar solution (500 c.c., 0·4 per cent.). The suspensions were incubated at 30° C. and, after the sugar had completely disappeared, the supernatants were decanted out, neutralised with lime and then concentrated to a small bulk. The dark coloured concentrates, thus obtained, were then analysed for their organic carbon contents (Bhaskaran *et al.*, 1936), and calculated quantities (50 c.c.) containing 132 mg. of organic carbon, added to sterile, triple strength Ashby's medium (25 c.c.) without sugar. Water was added to make up the volume to 100 c.c. in each case and the

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mixtures inoculated with soil (a local specimen ; red sandy loam). They were then incubated at 30° C. Representative specimens were taken out at 4-day intervals and analysed for their organic carbon and total nitrogen contents (Bhaskaran *et al.*, *loc. cit.*). The results have been presented in Table I.

TABLE I.

| Time in days | Total organic carbon (in mg.) | Total nitrogen (in mg.) |
|---|---|---|
| 0 | 132 | Nil |
| 4 | 120 | 0·42 |
| 8 | 115 | 0·95 |
| 12 | 106 | 1·50 |

Extension beyond 12 days did not result in any appreciable increase in nitrogen fixation.

It may be seen that although the total quantity of nitrogen fixed was comparatively poor, the amount of carbon used up was also very small. The ratio of the former to the latter was as 1 : 17 which may be regarded as being quite satisfactory when compared with that obtained (1 : 60) when the carbohydrate is applied directly to the soil.

*Effect of adding the residue after fermentation directly to mineral medium.*—To 50 c.c. lots of 1 per cent. sugar solution, fresh garden soil (10 g.) was added and the mixtures allowed to ferment in small narrow mouthed bottles which were filled up to the brim. When the sugar had disappeared, the entire quantities of the fermented products were transferred to larger flasks containing 25 c.c. each of triple strength Ashby's medium (without sugar). The remaining part of the procedure was the same as that described before.

TABLE II.

| Time in days | Total organic carbon (in mg.) | Total nitrogen (in mg.) |
|---|---|---|
| 0 | 93 | Nil |
| 4 | 82 | 0·70 |
| 8 | 58 | 1·54 |
| 12 | 55 | 2·06 |

It may be noted (Table II) that in these cases, there was more rapid loss of carbon than in the previous experiment. The fixation of nitrogen was also correspondingly increased so that the ratio of nitrogen fixed to the carbon utilised was maintained more or less the same.

*Addition of the concentrate together with the carbohydrate.*—In both the previous experiments, very little carbon was used up in 12 days : extension beyond that period did not lead to either greater consumption of carbon or further fixation of nitrogen. The apparent equilibrium thus attained may have been due to one of the following causes :—(a) the residue being unfermentable, (b) the products attendant on the fixation being inhibitive to further utilisation of organic carbon, or (c) the flora (which were derived from a small quantity of dry soil) not being sufficiently large in number or otherwise inadequate to ferment the entire quantity of organic matter. It is probable that the restricted air supply in the flasks was also partly responsible for the rapid slackening of fermentation. Of these, (a) appeared improbable, because the added concentrate was of uniform composition, so that there could not be any unfermented residue which was chemically different from the fermented portion. The second cause (b) is probable, as also the effect of restricted air supply. The third one (c) also appeared possible, so some experiments were conducted adding sugar (together with the mineral solution) first to the soil (10 g.) so as to facilitate rapid multiplication of the fermenting organisms. After 3 days, equal volumes of the fermenting medium (which still contained some sugar) were treated with varying quantities of the mixed calcium salts. They were then incubated at 30° C. and the carbon and nitrogen contents of representative samples determined as before (Tables III and IV).

TABLE III.

| Time in days | Organic carbon (in mg.) | | | |
|---|---|---|---|---|
| | Sugar solution alone (control) | Sugar solution + 20 mg. equivalent of mixed calcium salts | Sugar solution + 40 mg. equivalent of mixed calcium salts | Sugar solution + 80 mg. equivalent of mixed calcium salts |
| 0 | 100·2 | 120·2 | 140·2 | 180·2 |
| 4 | 97·0 | 118·5 | 137·7 | 170·0 |
| 8 | 48·8 | 84·0 | 98·8 | 103·0 |
| 12 | 47·0 | 66·8 | 75·5 | 86·4 |

TABLE IV.

| Time in days | Total nitrogen (in mg.) | | | |
| --- | --- | --- | --- | --- |
| | Sugar solution alone (control) | Sugar solution + 20 mg. equivalent of mixed calcium salts | Sugar solution + 40 mg. equivalent of mixed calcium salts | Sugar solution + 80 mg. equivalent of mixed calcium salts |
| 0 | Nil | Nil | Nil | Nil |
| 4 | 0·84 | 0·93 | 0·97 | 0·93 |
| 8 | 2·6 | 3·01 | 3·11 | 3·10 |
| 12 | 3·5 | 4·21 | 4·46 | 4·70 |

Assuming that the same quantity of sugar was utilised in each case and that the corresponding fixation was also the same, it may be reckoned that when 20 mg. equivalent of the mixed salts was added, only about 3 mg. was used up in fixing 0·7 mg. of nitrogen. When 40 mg. was used, only about 12 mg. was utilised in fixing 0·96 mg. of nitrogen; when 80 mg. was added, 40 mg. was spent in fixing 12 mg. These results show that the mixed calcium salts were utilised most efficiently only when they were added in small quantities.

*Effect of adding the concentrate after the sugar was fully used up.*—In the foregoing experiments, the quantities of sugar started with were comparatively large. This might have had some influence on the utilisation of the added calcium salts. Moreover, the concentrate was added before the sugar

TABLE V.

| Time in days | Organic carbon as mg. in 100 c.c. medium | | Nitrogen fixed (in mg.) by the mixed calcium salts (Experiment—Control) |
| --- | --- | --- | --- |
| | Sugar alone (control) | Sugar + 20 mg. equivalent of mixed calcium salts | |
| 0 | 28·4 | 48·7 | Nil |
| 4 | .. | 38·1 | 0·77 |
| 8 | 28·0 | 34·8 | 0·80 |
| 12 | 24·0 | 31·6 | 0·83 |

was entirely used up, so that it was difficult to determine as to how far the calcium salts alone were utilised at the time of examination. With a view to eliminating these two possible defects, a new series of experiments was conducted in which only a small quantity of sugar was added in each case as the starter. The mixed calcium salts (corresponding to 20 mg. of organic carbon in each case) were added only after the entire quantity of sugar had disappeared. The results, which are presented in Table V, show that quite useful amounts of nitrogen can be fixed at comparatively small expense of carbon. The ratio of the former to the latter (1 : 20·6) is similar to that obtained in the earlier series, and compares favourably with that obtained by other methods.

*Nitrogen fixation in soils.*—With a view to determining whether similar fixations could be obtained under ordinary soil conditions, specimens from two different localities (red sandy loam from Bangalore and *Kalar* soil from Sind ; 10 g. each) were weighed into shallow dishes and treated with 20 mg. equivalent each of mixed calcium salts. They were then moistened to 50 per cent. saturation and incubated at 30° C. Organic carbon and total nitrogen contents were determined in the usual way.

TABLE VI.

*Bangalore Soil.*

| Time in days | Organic carbon (in mg.) | | Nitrogen fixed (in mg.) (Experiment—Control) |
|:---:|:---:|:---:|:---:|
| | Soil + 20 mg. equivalent of mixed calcium salts | Carbon utilised | |
| 0 | 70·5 | Nil | Nil |
| 4 | 65·1 | 5·4 | 0·32 |
| 12 | 61·6 | 9·9 | 0·88 |
| 17 | 58·2 | 12·3 | 0·93 |

In both the cases, the untreated soil did not show any appreciable variation in organic carbon, so the corresponding figures have not been recorded.

It may be noted that the efficiency of fixation was very high in the earlier stages, the ratio of nitrogen fixed to carbon utilised being as close as 1 : 7 in the *Kalar* soil. Between the 4th and the 17th days, increasing amounts of carbon were utilised with proportionately less fixation of nitrogen. The

ultimate return was still very satisfactory being as 1 : 13 in one soil and 1 : 17 in the other.

TABLE VII.

Kalar *Soil* (*Sind*).

| Time in days | Organic carbon (in mg.) | | Nitrogen fixed (in mg.) (Experiment—Control) |
| --- | --- | --- | --- |
| | Soil + 20 mg. equivalent of mixed calcium salts | Carbon utilised | |
| 0 | 69·0 | Nil | Nil |
| 4 | 66·3 | 3·6 | 0·50 |
| 8 | 62·3 | 7·6 | 0·66 |
| 12 | 57·1 | 12·8 | .. |
| 17 | 54·7 | 15·2 | 0·91 |

In both the cases, the untreated soil did not show any appreciable variation in organic carbon, so the corresponding figures have not been recorded.

The quantities of the mixed calcium salts added in the foregoing experiments would correspond approximately to 2 tons of organic carbon per acre. The nitrogen fixed by these would correspond to about 2 cwt., *i.e.*, about 13·5 cwt. of protein or about 2·5 tons of a good seed-cake.

## Discussion.

The results of the present enquiry have revealed an entirely new and a highly important aspect of nitrogen fixation in the soil. They also show that, under favourable conditions, the biological method of fixation can be a practical success.

Attention has already been drawn to the fact that although direct application of various types of carbonaceous materials leads to fixation of nitrogen the quantities thus added to the soil have always remained small, so that the process can be scarcely regarded as being economical. By converting such materials into acids and their salts, it has been possible to greatly improve the efficiency of fixation.

The biological mechanism of this fixation is still obscure. The previous findings of Bhaskaran (1936[2]) would suggest that Azotobacter does not make any appreciable use of the residual organic matter, so that it would appear

that the other organisms of the soil are concerned in the fixation. Further researches on this aspect of the problem is needed before any definite conclusions can be drawn.

The precise nature of the organic substances utilised by the mixed flora in the fixation also require elucidation. The concentrate obtained after anaerobic fermentation in the soil contained a number of other substances in addition to organic acids. It would be of interest to determine the effect of the dissolved iron, aluminium and other minerals on the fixation. The effects of individual acids or their salts would also deserve careful study.

Although the foregoing study was carried out in presence of the mixed flora of the soil, it would still be necessary to repeat them with pots and small plots before the procedure can be extended to the field. Systematic observations on the ammonification and nitrification of the fixed nitrogen, as also its general availability to crops, will also be needed before the practical value of the new method can be established. Researches on these and other aspects of the problem are in progress and will be reported in subsequent communications.

## Summary.

(1) When fairly large quantities of mixed calcium salts of organic acids (obtained after anaerobic fermentation of sugar) are added to a mineral medium containing soil, only a small portion of the added organic matter is used up in the course of 12 days. The quantity of nitrogen fixed, though small, is proportionately high when compared with the carbon utilised.

(2) When the acid products are added directly to the mineral medium, (without neutralisation) there is fairly rapid utilisation of carbon. There is also correspondingly greater fixation of nitrogen.

(3) When varying quantities of acid products are added together with the sugar, the best return of nitrogen for the carbon utilised is obtained when the mixed calcium salts are of the order of 20 mg. of the organic carbon to 10 g. of the soil.

(4) When the mixed calcium salts are added after the sugar is completely used up, there is enhanced fixation of nitrogen, the ratio of fixed nitrogen to the carbon utilised being as 1 : 20.

(5) Trials with two different types of soil (one, a red sandy loam, and the other, an alkali soil) showed that the mixed calcium salts are used nearly to the same extent in both the cases. The corresponding fixation is also similar, yielding ratios ranging between 1 : 13 and 1 : 17,

(6)  The significance of the foregoing observations and their possible extension to field practice are discussed.

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# STUDIES ON INULINASE.

By Nuggehalli Keshav Iyengar
AND
Motnahalli Sreenivasaya.
*(From the Department of Biochemistry, Indian Institute of Science, Bangalore.)*

ALTHOUGH Dragendorff[1] had observed the inulin-splitting power in several vegetable structures, Green[2] appears to have been the first to establish the presence of the enzyme in the germinating artichoke and to describe some of its properties and actions in relation to the germination of the tuber. Bourquelot[3] showed that the enzyme occurs also in certain fungi, which was later confirmed by Dean[4] who demonstrated its presence in *Aspergillus niger* and *penicillium glaucum*. While studying the intracellular enzymes of lower fungi, Dox[5] found inulinase to occur in high concentration in aqueous macerations of *Penicillium camemberti*, capable of hydrolysing inulin to the extent of 92 per cent.

The enzyme has also been found to occur in Lepidopteral larvæ[6] fresh placental mash,[7] pneumococcus,[8] while its presence in honey,[9] is strongly suspected. Pancreatic and intestinal juices normally do not contain this enzyme, but its formation in the intestines has been induced by feeding dogs with inulin-rich foods.[10] Neuberg and Rosenthal have found that Taka diastase hydrolyses inulin to the extent of 12·2 per cent. in four hours. Extracts from green inulin-containing plants, in general, exhibit feeble enzymic activity and the most active preparations so far are obtained from cultures of fungi.

Water extracts are just as active as those of 70 per cent. glycerine. Invertase does not attack inulin but the reducing impurities if associated with inulin are split by inulinase. The specificity of inulinase has been often questioned and the constant association of an invertase with the enzyme has led to the contention that invertase is an indispensable and necessary component of the inulinase system for effecting a complete hydrolysis of inulin. Inulinase preparations have so far not been entirely freed from their invertase component and therefore, the rôle of invertase in the hydrolysis of inulin, still remains an unsettled question.

By the comparative inhibiting effects of the serum on the action of aspergillus extracts in inulin and sucrose digestions, Saiki[11] sought to individualise an inulinase and a sucrase and disproved that the two effects of the

aspergillus extract are attributable to a single enzyme. By subcutaneous injection of inulinase an antibody for the enzyme can be produced in rabbit's serum. The anti-serum was found to exert different degrees of inhibitory action upon the inulin-digesting and sucrase-inverting activities of inulinase preparations. Presumably therefore, concludes the author, the inulin splitting action and the sucrase activity exist independently in the preparation of so-called "inulinase" from *aspergillus niger*.

Pringsheim and Kohn[12] have effected a partial separation of the two enzymes with $CaHPO_4$ as the adsorbent, and have found that the enzyme acts at the optimum PH of $3 \cdot 8$ with citrate buffer.

The present investigation relates to a study of the fungus inulinase with a view to elucidate its chemical nature.

*Experimental.*

Exposure of a quantity of minced and cooked artichoke for about a week, resulted in the growth of a mass of fungus, a pure culture of which was obtained by the single cell culture method, employing an artichoke nutrient media. An examination of a trial culture of the fungus revealed the presence of an active inulinase and stock cultures of this fungus (*aspergillus sp* ?) constituted our source of the enzyme.

The fungus was cultured on a nutrient medium consisting of Magnesium sulphate 2 gms., Sodium di-hydrogen phosphate 4 gms., Ammonium sulphate 8 gms. and Inulin, which was provided in the form of an aqueous extract of the tubers of artichoke. The extract was prepared by cooking 5 lbs. of minced artichoke with 2 litres of water and filtering the mass through cheese cloth. The extract was made up to 4 litres to which the inorganic nutrients were added—and this served as the medium for culturing the fungus.

The medium was placed in several flat bottomed pasteur flasks to a depth of about 5 cms. and after sterilisation, 1 c.c. of a suspension of the spores in sterile water was sown into each of the flasks. The cultures developed rapidly at the laboratory temperature (25–27° C.). In the course of 3–4 days the whole surface became covered with a felt of dense white mycelium which could be easily removed from the flask in one mass.

These masses of mycelia were washed for a few minutes in running water to remove the adhering culture solution, squeezed in a tincture press to remove as much of the water as possible and pressed between thick folds of filter paper. The mass thus obtained was treated with anhydrous acetone for 10 minutes and filtered. The process was repeated twice when a dry powder was obtained. This was washed with ether at the filter pump, sucked as dry as possible, and subsequently dried *in vacuo* over sulphuric acid. The

resulting greyish white powder served as the source of enzyme for all the subsequent experiments.

*Enzyme make-up of the powder.*—The powder thus obtained was then analysed for its enzymes. An extract obtained by macerating 5 gms. of the powder with 100 c.c. of toluenated water for 24 hours at room temperature, was employed for this purpose. Experiments revealed the presence of emulsin maltase, diastase and invertase.

With a view to determine the optimum conditions for the formation of the enzyme in high concentration in relation to the composition of the inorganic nutrients of the medium, the fungus was cultured on five different media whose compositions are tabulated in Table I.

TABLE I.

| Media No. | I | II | III | IV | V |
|---|---|---|---|---|---|
| $NaH_2PO_4$ (gms.) .. | 4 | 2·5 | 5·5 | 4 | 4 |
| $NH_4NO_3$ (gms.).. .. | 8 | 8 | 8 | 4 | 12 |
| KCl (gms.) .. .. | 2 | 2 | 2 | 2 | 2 |
| $MgSO_4$ (gms.) .. .. | 2 | 2 | 2 | 2 | 2 |
| Artichoke Extract (litres) | 4 | 4 | 4 | 4 | 4 |

Considering medium No. 1 as the standard it will be seen from the table that in numbers 2 and 3, the phosphorus content has been varied while the nitrogen content has been varied in 4 and 5. The fungus growths obtained on these media were prepared as described before, for analysis, the results of which are given in Table II.

Enzyme activities of the preparations have been expressed in terms of the milligrams of reducing sugar produced by a unit weight or volume of the preparation or extract when it acts upon their respective substrates, Inulin or sucrose, under standardised conditions of substrate concentration, optimum reaction time and temperature. Inulinase activity was determined with 0·2 gm. quantities of the preparation acting on 5 c.c. of a 1 per cent. solution of unilin for 30 minutes at 320° C., an optimum reaction of 3·8 pH being maintained by citrate buffer. Invertase activity was estimated with 0·2 gms. of the preparation acting on 5 c.c. of a 0·5 per cent. sucrose for 30 minutes at 30° C. an optimum reaction of 6·8 pH being maintained by Sorensen's M/15 phosphate buffer.

TABLE II.

*(Percentages on the Weight of Moisture Free Material.)*

|  | I | II | III | IV | V |
|---|---|---|---|---|---|
| Ash .. .. .. | 2·66 | 2·41 | 2·72 | 2·35 | 2·79 |
| Total Nitrogen.. .. | 3·42 | 3·33 | 3·39 | 2·05 | 4·92 |
| Phosphorus ($P_2O_5$) .. | 0·82 | 0·53 | 1·25 | 0·78 | 0·75 |
| Inulinase (per gram) .. | 135·0 | 77·5 | 165·0 | 128·0 | 132·5 |
| Invertase (per gram) .. | 130·0 | 75·0 | 160·0 | 125·0 | 128·0 |
| Yield of fungus (gms.) .. | 25·2 | 20·4 | 29·4 | .. | .. |

It will be seen from Table II that the inulinase and invertase activities of the preparations vary in a significant manner. Preparations I, IV and V which have been cultured on media having the same concentration of phosphate, possess practically the same activity, while preparations II and III which have been obtained on media whose phosphate content was varied as compared with that of the first media, show a significant variation in the activity of both the enzymes, in direct proportion to the phosphorus content of the preparations. It is interesting to find that the formation of both inulinase and invertase are influenced by phosphate practically to the same extent. It will also be observed that the total nitrogen content of the preparations does not appear to have any relationship with enzymic acitvity of the preparations. If the enzyme activity is calculated on a common basis taking preparation II as the standard, we obtain the results given in Table III;

TABLE III.

| Powder No. | $P_2O_5$ | Inulinase activity in mgms. of reducing sugar | |
|---|---|---|---|
|  |  | Found | Calculated |
| 1 | 0·82 | 135 | 117 |
| 2 | 0·53 | 77 | .. |
| 3 | 1·25 | 165 | 181 |

the agreement between the calculated and the experimental values is not unsatisfactory, if we consider that the fungus powders may be associated with inert and phosphorus containing material. The results, however, definitely point to the possibility of phosphorus playing an essential rôle in the formation of inulinase.

Since the fungus powder contains several types of inert materials insoluble in water, it was thought that aqueous extracts obtained by the cytolytic maceration of the fungus powders might reveal a better correlation between the enzyme activity and the phosphorus or nitrogen contents. The extract was prepared by treating the finely powdered fungus preparation with toluenated water (1 : 5) and allowing the maceration to proceed overnight at room temperature. After 20 hours, the extract was filtered and the clear light red filtrate provided the enzyme extract.

It may be mentioned that such extracts are not usually standardised or specified by determinations of at least their total solid or nitrogen contents. Such data would be useful in comparing the results of different workers and in understanding the divergent results often reported in literature. In the present study, the extracts have been analysed for their content of total solids, inorganic constituents, total and amino nitrogens, phosphorus and hydrogen ions (pH), and a determination of the electrical conductivity and depression of the freezing point has also been carried out with the extract.

TABLE IV.

| Extract from fungus Preparation No. | Milligrams per c.c. of the extract | | | | | | | | Enzyme activity in mgms. of reducing sugar | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total solids | Ash | Total nitrogen | Amino nitrogen | Phosphorus $P_2O_5$ | K $10^{-5}$ | O C | pH | Inulinase | Invertase |
| 1 | 30·6 | 1·9 | 1·71 | 0·91 | 0·41 | 452 | 0·46 | 5·3 | 7·0 | 6·5 |
| 2 | 30·1 | 1·7 | 1·65 | 0·85 | 0·30 | 450 | 0·44 | 5·3 | 4·5 | 4·2 |
| 3 | 31·1 | 2·2 | 1·67 | 0·87 | 0·53 | 453 | 0·46 | 5·1 | 8·4 | 8·0 |

If the inulinase activity can be expressed on the basis of total phosphorus content of the extracts taking that extract which contains the least amount of the constituent as the standard, we obtain the following results given in Table V.

TABLE V.

| Extracts from powder | P$_2$O$_5$ mgms. per c.c. | Inulinase activity per c.c. in milligrams of sugar | |
| :---: | :---: | :---: | :---: |
| | | Experimental | Calculated |
| 1 | 0·41 | 7·0 | 6 |
| 2 | 0·30 | 4·5 | .. |
| 3 | 0·53 | 8·4 | 7·0 |

That the total and amino nitrogens of the enzyme extracts of the fungus powders have no relation with their enzymic activities is illustrated by Table VI.

TABLE VI.

| Extract | Total Nitrogen | Amino Nitrogen | Inulinase activity per c.c. in milligrams of sugar |
| :---: | :---: | :---: | :---: |
| | Milligrams per c. c. | | |
| 1 | 1·71 | 0·91 | 7·0 |
| 2 | 1·16 | 0·55 | 7·0 |
| 3 | 2·91 | 1·51 | 7·2 |

A study of the Tables V and VI will reveal, that while there is a significant difference in the enzymic activity with a variation in the concentration of phosphorus, the total and amino nitrogen contents of the extracts do not bear any relation to the enzyme activity.

*Summary.*

1.   Highly active preparations of inulinase can be obtained from a species of *aspergillus* which is grown on artichoke nutrient media. Comparative culture experiments have revealed that phosphates definitely stimulate the formation and enrich the inulinase content of the preparations.

2.   The fungus preparation can be preserved for months in a dry and active condition after treatment of the crop with anhydrous acetone. The inulinase can be extracted from this powder by maceration with toluene saturated water at room temperature, and stable extracts are thus obtained which maintain their enzymic activity unimpaired for months.

3. It has been found that a definite relationship exists between the phosphorus content of the preparation and their inulinase activity both in the case of the powders and their maceration extracts, while the total and amino nitrogens of the extract bear no relation with its enzyme activity.

In conclusion we wish to record our appreciation of the assistance rendered by Mr. H. R. David, Bacteriological Laboratory Assistant, in securing large quantities of the fungus crop required for these investigations. Our best thanks are due to Mr. B. N. Sastri for his many useful suggestions and discussion.

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# THE LIFE-HISTORY OF *CHENOPODIUM ALBUM* LINN.

BY H. R. BHARGAVA.

*(From the Department of Botany, Agra College, Agra.)*

## *Introduction.*

THERE has been a large amount of work on the vegetative anatomy of the Chenopodiaceæ (Fron, 1899; Wilson, 1924; Artschwager, 1920, 1926, 1927; and others) but the floral development is not known fully in any other plant except *Beta vulgaris*. As the following review will show, most of the earlier investigations deal with a few important stages here and there without giving a connected account of the life-history of the plant chosen for investigation. The present study was undertaken with a view to provide a fairly complete description of the life-history of one member of this family and to utilise this information for a forthcoming discussion of the general relationships of the Centrospermales.

## *Historical.*

Hegelmaier (1855) observed a free nuclear endosperm in *Salsola kali* and *Kochia scoparia*. Fischer (1880) stated that in *Chenopodium fœtidum* the development of the embryo sac is of the normal type. Cohn (1914) and Romell (1919) found the same in *Atriplex hortensis* and *Salsola kali* respectively. Souéges (1920) made a thorough study of the development of the embryo in *Chenopodium Bonus-Henricus* and Williams (1932) in *Kochia scoparia*. Artschwager (1927) gave a fairly comprehensive account of the development of flowers and seed in *Beta vulgaris*. Oksijuk (1927), and later Artschwager and Starrett (1933) observed an embryo sac haustorium (cæcum) and increase in the number of antipodal cells in the same plant. Favorsky (1928) working on the same species reported the occurrence of polyembryony in closed buds and attributes this to nucellar budding—a phenomenon which is stated by Artschwager and Starrett (1933) to be definitely absent in their material. Billings (1934) described development of the pollen grains in *Atriplex hymenelytra* and also the sex chromosome mechanism in this plant. Very recently G. O. Cooper (1935) has studied microsporogenesis and pollen development in *Kochia trichophylla*, *K. scoparia*, *Chenopodium hybridum*, *C. album*, *Atriplex patula* var. *hastata* and *Salsola kali*.

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*Material and Methods.*

The material used for this investigation was collected locally and fixed in formalin-acetic-alcohol and Nawaschin's fluid. Both the fixatives gave good results. Sections were cut 4–10 microns thick, stained in Heidenhain's Iron-alum Hæmatoxylin, differentiated in an aqueous soultion of picric acid (Maheshwari, 1933) and counterstained with Fast green. Combinations of Safranin and Fast green, Crystal violet and Erythrosin, and Delafield's Hæmatoxylin alone were also used for special purposes.

*Investigation.*

*Flower.*—The flowers are minute, bisexual and arranged in axillary clusters. Bracts and bracteoles are absent. The perianth is five-lobed. The five stamens are situated opposite to the perianth lobes and are united at the base to form a very short staminal tube just as in *Digera arvensis*
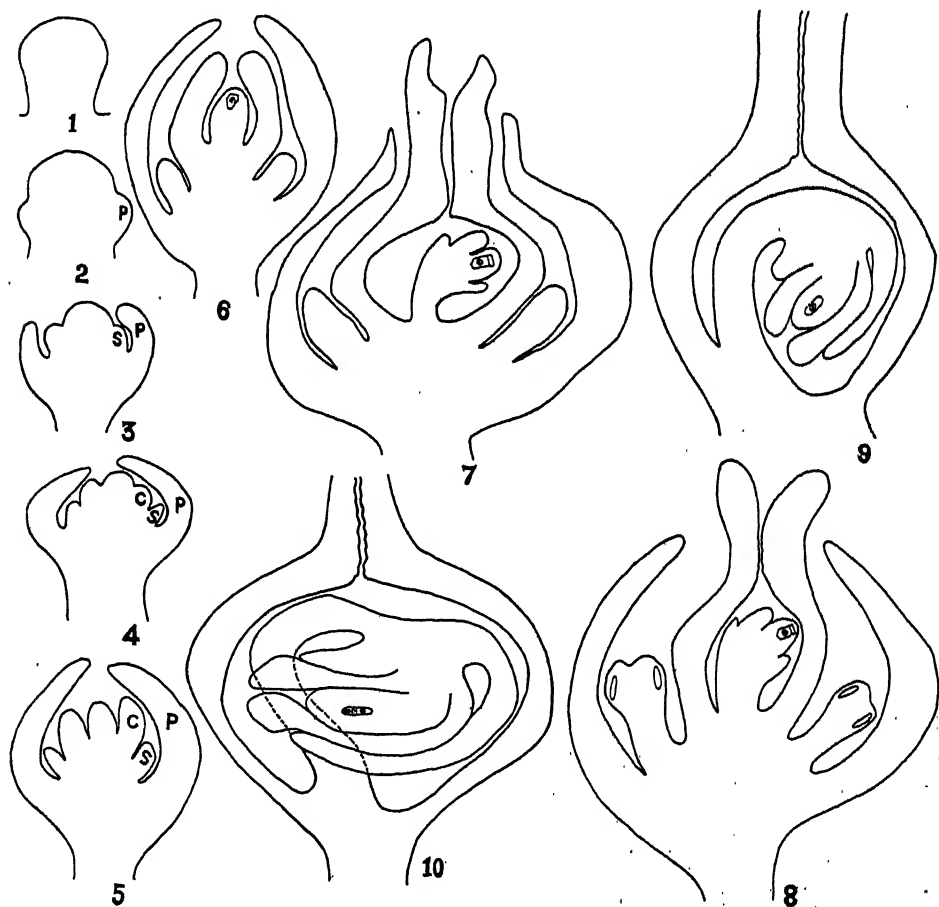
(Joshi and Rao, 1934). The ovary contains a single seed which is compressed, black and shining.

*Organogeny.*—The development of the floral organs is strictly acropetal as in *Beta vulgaris* (Artschwager, 1927). The individual flower primordium appears first as a conical mammillate projection (Fig. 1) on which the five perianth lobes (Fig. 2) soon appear in a single whorl. Then come the stamens (Fig. 3) and last of all the two carpels[1] (Figs. 4, 5). The tip of the flower primordium develops into the ovule. The two carpels grow upwards enclosing the ovule and ending in a bilobed stigma, which is clothed with papillate cells.

In the beginning the carpels develop much faster than the stamens and even the anther lobes are not marked out at the time when the primary archesporial cell is visible in the nucellus (Fig. 6) and has even cut off a wall cell (Fig. 7). But soon after, when there is still the megaspore mother cell in the nucellus, the anther lobes are first clearly outlined (Fig. 8.) Further informatin about the relative development of the anther and ovule is given on page 191.

*Vascular anatomy.*—The vascular tissue of the floral receptacle (Fig. 11) sends out five traces to the perianth (Fig. 12), each lobe receiving a single trace which remains undivided throughout its entire course (Figs. 12–17). The staminal traces, one to each stamen, depart at a slightly higher level (Fig. 13). Now, whatever vascular tissue is left behind in the thalamus forms one bundle (Figs. 13, 14) which is often amphiphloic or even concentric. This directly enters into the single ovule and the carpels are thus left without any vascular supply. The ovary wall is extremely thin and lacunar and has practically no space for any vascular bundle. Fundamentally the carpel is a three-trace organ (Eames, 1931) and the condition in *Chenopodium album* will, therefore, have to be regarded as extremely reduced.

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FIGS. 1–10.—Organogeny and development of the ovule. Fig. 1.—L.S. Young flower primordium. Fig. 2.—Same, appearance of perianth (P). Fig. 3.—Appearance of stamens (S). Figs. 4–5.—Appearance of carpels (C). Fig. 6.—L.S. Flower, the archesporial cell has differentiated in the nucellus. Fig. 7.—Same, at megaspore mother cell stage; the integuments have developed. Note that the anthers have not yet differentiated. Fig. 8.—Older stage, the anthers have now differentiated. Fig. 9.—L.S. Ovary showing orientation of the ovule when the megaspore mother cell is in synizesis. Fig. 10.—Same, at megaspore tetrad stage. $\times$ 160.

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[1] If I understand Thomas (1931) correctly, the gynæcium of *Chenopodium album* may also be interpreted to consist of only a single carpel which has developed as an annular outgrowth or 'cupule' surrounding the single basal ovule.
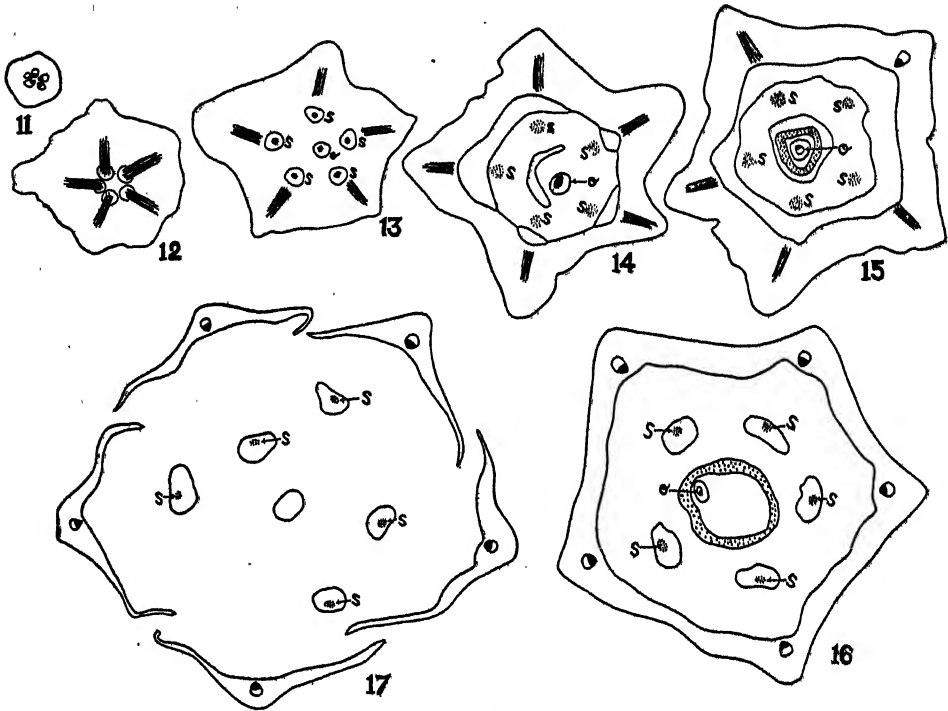
FIGS. 11-17.—Cross-sections of the flower at successive levels. Fig. 11.—T.S. of the flower showing the vascular tissue of the thalamus. Fig. 12.—Departure of the perianth traces. Fig. 13.—Perianth traces already gone out and the appearance of the staminal traces and the single ovular trace. Figs. 14-16.—Showing the traces to the perianth lobes, stamens and ovule. Fig. 17.—T.S. of the flower at the base of the style, the five perianth lobes have separated. $\times$ 40. *s.*, staminal trace. *o.*, ovular trace.

*Microsporogenesis.*—Soon after the anther assumes the four-lobed appearance in transverse section, there appears in each corner a hypodermal archesporial cell which is distinguishable from the other cells by its larger nucleus and denser contents (Fig. 18). This divides periclinally to form the primary parietal cell and the primary sporogenous cell (Fig. 19). The former divides first by an anticlinal wall (Fig. 20) and then by further anticlinal and periclinal divisions gives rise to an outer (the endothecium) and an inner layer (Fig. 21). The latter divides again to produce one middle layer and the tapetum (Fig. 22). Thus the tapetum is definitely derived from the primary parietal layer, while Artschwager (1927; p. 12) reports that in *Beta vulgaris* it "is separated from the primary sporogenous tissue". The primary sporogenous cell divides to form a plate of about ten cells in each lobe in transverse section. Longitudinally it extends to a depth of about fifteen cells. The endothecium develops the usual fibrous thickenings at maturity while the

middle layer degenerates early and practically disappears by the time the reduction divisions are over.
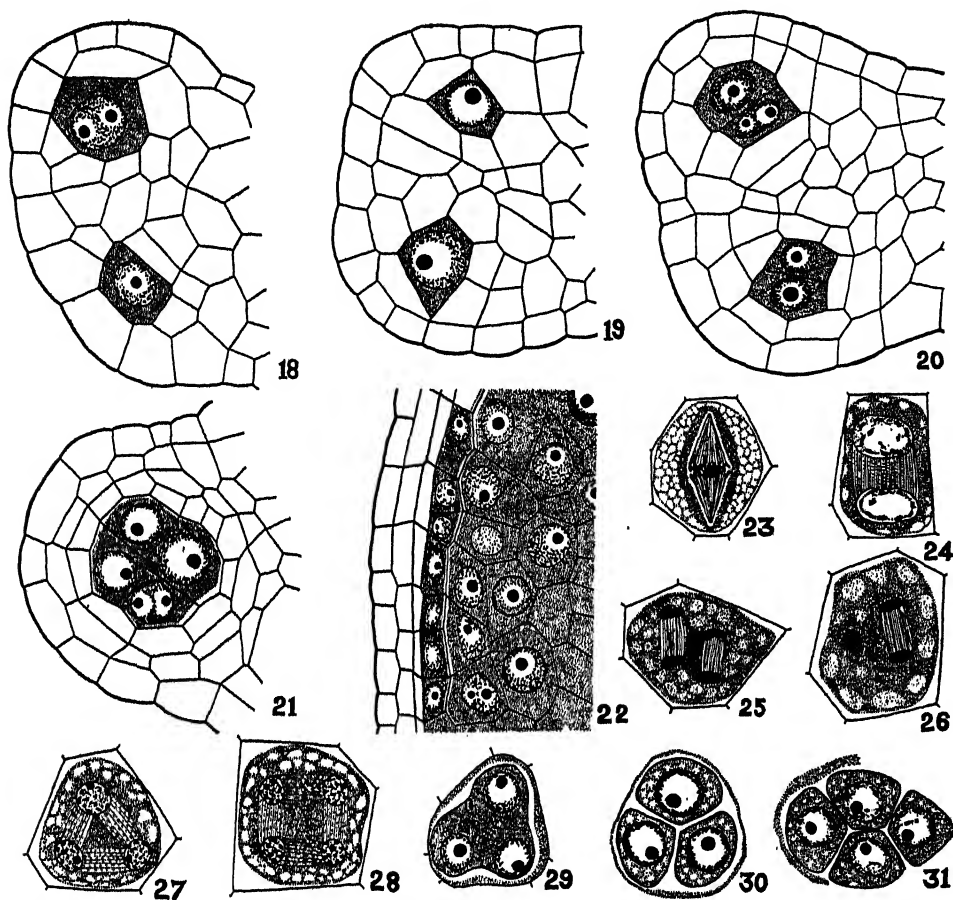


FIGS. 18–21.—Parts of transverse sections of young anthers. Fig. 18.—Hypodermal archesporial cell in each anther lobe. Fig. 19.—Primary wall cell and the primary sporogenous cell. Fig. 20.—Older stage, two sporogenous cells in each lobe. Fig. 21.—One anther lobe, showing two wall layers and four sporogenous cells. ✕ 860.

FIG. 22.—Part of a longitudinal section of an anther showing three wall layers of which the innermost is the tapetum; and the microspore mother cells. ✕ 860.

FIGS. 23–31.—Stages in division of the microspore mother cells and development of microspores. ✕ 860.

The microspore mother cells do not round off or separate from each other but remain in contact throughout the whole process of meiosis until the final dissolution of their walls. During the prophase of the first reduction division the cytoplasm begins to recede from the mother cell wall. The metaphase

spindle of the first reduction division (Fig. 23) is surrounded by a clear space which, in its turn, is surrounded by a dense cytoplasmic zone on whose outside lies a more vacuolated area.   No cell plate (Fig. 24) is laid down after this division and the two daughter nuclei immediately enter upon the second reduction division (Figs. 25–28).   The spindles may lie either parallel or at right angles to each other (Figs. 25, 26).   The cytoplasm, which lies between the two spindles, is denser than the rest which is more or less vacuolate (Figs. 25, 26)—a fact also observed by G. O. Cooper (1935) in the species worked out by him.   Quadripartition of the  mother cells is effected by invaginations of the cytoplasm developing at four equidistant points on the periphery (Fig. 29) and gradually proceeding inward.   I have not been able to observe any cell plates as reported by G. O. Cooper (1935) in *Chenopodium album*, *C. hybridum* and *Kochia trichophylla*.   The rate of furrowing appears to be very rapid, for many cases were  observed where the furrows had just started and others, where the  microspores had just been formed but the intervening stages were very rare.

About the tetra-nucleate stage the wall of the mother cell becomes mucilaginous (Fig. 29), but this is not always seen clearly in sections stained with Iron-alum Hæmatoxylin.   Much better views were obtained on staining the slides in Delafield's Hæmatoxylin or giving a touch of Fast green after the slides had been previously stained in Heidenhain's Hæmatoxylin.   It could not be determined whether this mucilagenous wall is due to a special secretion from the cytoplasm, as reported in *Lathræa clandestina* (Gates, 1924), *Melilotus alba* (Castetter, 1925), *Ipomœa batatas* (Juliano, 1935) and *Trianthema monogyna* (Bhargava, 1935), or it is a product of the swelling and gelatinisation of the secondary strata of the mother cell wall as in *Digera arvensis* (Puri and Singh, 1935) and also suggested by Farr (1916).

The arrangement of the microspores may be either tetrahedral (Fig. 30) or isobilateral (Fig. 31).   The mucilaginous sheath now dissolves away and the young microspores become free.

There is a surprising difference in the reports of chromosome number in *Chenopodium album*.   Winge (1917) reported nine as the haploid number in this species, but G. O. Cooper (1935) has recently given it as eighteen. In my own preparations at the diakinesis stage, I made several counts[2] and I find that the latter report is correct.

*Tapetum.*—The tapetal cells are uni-nucleate in the beginning (Fig. 22) but through mitotic divisions, which take place at the time the microspore

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[2] I am indebted to Dr. C. C. John who kindly helped me in the counting of chromosomes.

mother cells are in synizesis, they become two- to four-nucleate (Figs. 32–33). A fusion of these nuclei has also been observed (Fig. 34) and the large secondary nuclei thus formed show several nucleoli (Fig. 35). In other plants of this family that have been investigated so far, *i.e.*, *Beta vulgaris* (Artschwager, 1927), *Atriplex hymenelytra* (Billings, 1934), *Kochia trichophylla*, *K. scoparia*, *Atriplex patula* var. *hastata*, *Chenopodium hybridum* and *Salsola kali* (G. O. Cooper, 1935), the tapetal cells are reported to be only bi-nucleate. The last named author has also included *Chenopodium album* in the list of plants showing bi-nucleate tapetal cells.
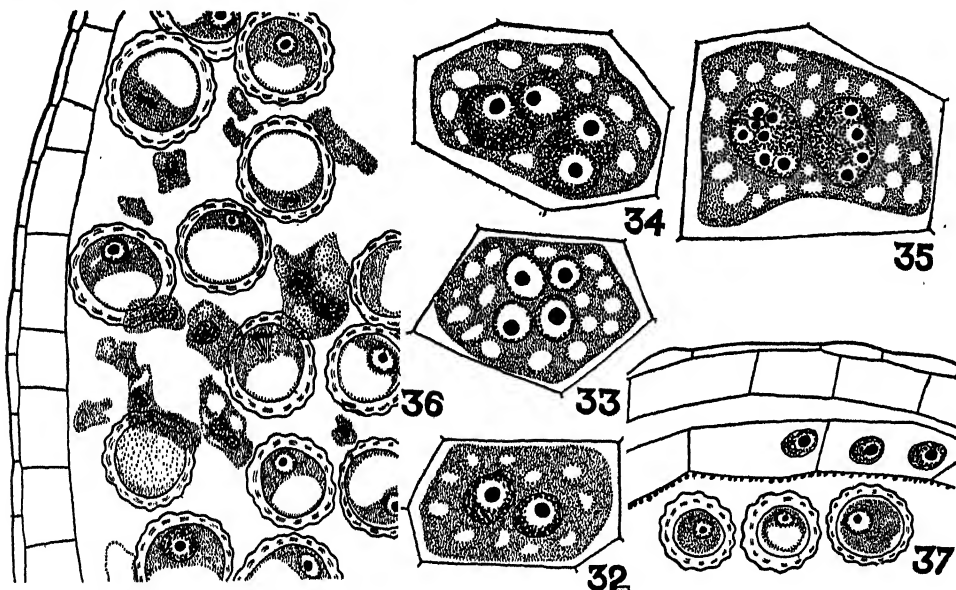


FIGS. 32–33.—Tapetal cells. Fig. 33.—Showing increase in number of nuclei. × 1174.
FIG. 34.—Tapetal cell showing fusion of the nuclei. × 1174.
FIG. 35.—Same, two secondary nuclei with many nucleoli. × 1174.
FIG. 36.—Part of a longitudinal section of an anther showing epidermis, endothecium and tapetal protoplasts lying in between the pollen grains. × 574.
FIG. 37.—Part of a transverse section of an anther at the microspore stage showing epidermis, endothecium and tapetum with small globular particles attached to its inner surface. × 574.

After the microspores have separated and the usual intine and exine have differentiated, the tapetal cells get loose, become amœboid and wander in between the developing microspores (Fig. 36). A gradual diminution of their cytoplasm proceeds simultaneously with the further growth of the pollen grains and finally their contents are entirely used up. The formation of a tapetal periplasmodium is unknown in the order Centrospermales (Schnarf, 1931). Only Rocén (1927) has reported some tendency towards

the formation of a false periplasmodium in *Bougainvillea glabra* and *Mirabilis jalapa.*

In sections of anthers, stained with safranin or crystal violet, there are seen at this stage some small globular particles attached to the inner surface of the tapetum (Fig. 37). They show the same staining reactions as the exine of the pollen grains. Similar punctate discs have been found in several other angiosperms by Ubisch (1927) and Kosmath (1927).

*Male gametophyte.*—The nucleus of the microspore (Fig. 38) moves near the wall and here it is surrounded by dense cytoplasm whilst most of the remaining space in the pollen grain is occupied by a large vacuole (Fig. 39).
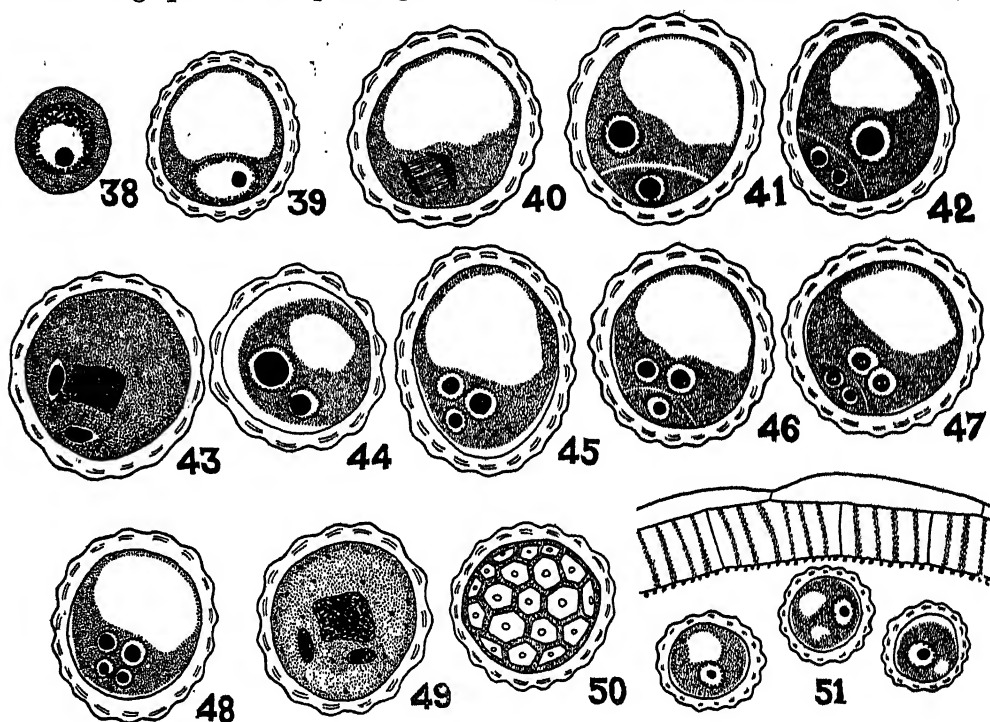


FIGS. 38–43.—Stages in development of the male gametophyte. × 1147.

FIGS. 44–49.—Abnormal pollen grains. Fig. 44.—Two-nucleate pollen grain; no wall was found between the tube and generative nuclei. Fig. 45.—Three-nucleate pollen grain showing the generative nucleus and two tube nuclei. Fig. 46.—Same, showing the generative cell and two vegetative nuclei. Fig. 47.—Four-nucleate pollen grain showing the two male nuclei in the generative cell and two vegetative nuclei. Fig. 48.—Same, showing two free male nuclei and two vegetative nuclei. Fig. 49.—Three-nucleate pollen grain showing the two spindle-shaped male nuclei and the degenerating tube nucleus. × 1147.

FIG. 50.—A pollen grain in surface view. × 1147.

FIG. 51.—Part of transverse section of an anther lobe showing small globular particles attached to the inner surface of the endothecium. × 574.

On division (Fig. 40) it produces a large tube cell and a small generative cell (Fig. 41). The outline of the tube nucleus often becomes wavy and it begins to show signs of degeneration at an early stage. The nucleus of the generative cell divides into two (Fig. 42) to form two male cells which soon become elongated and spindle-shaped[3] (Fig. 43). The cytoplasm immediately surrounding the male nuclei takes a much lighter stain than the general cytoplasm of the pollen grain, but the presence of a definite membrane between the two as reported by G. O. Cooper (1935) in *Kochia trichophylla* and the other plants worked out by him, could not be detected by me in spite of a careful study. Three-celled pollen grains have also been found in several other plants of the family—*Spinacea oleracea* (Tuschnjakowa, 1929), *Kochia trichophylla, K. scoparia, Chenopodium hybridum, Atriplex patula* var. *hastata* and *Salsola kali* (G. O. Cooper, 1935). In several cases no wall was observed between the tube and the generative nuclei (Fig. 44) and in rare cases the male nuclei also were lying free in the cytoplasm (Figs. 48, 49). The latter seems to be the usual condition in *Beta vulgaris* judging from the figures of Oksijuk (1927) and Artschwager and Starrett (1933).

It is of great interest to note that tri-nucleate pollen grains are characteristic of the whole order Centrospermales. So far two-nucleate pollen grains were reported only in *Boerhaavia* (Maheshwari, 1929 ; Bhargava, 1932) and five members of the family Portulacaceæ (Rocén, 1927 ; only *Claytonia sibirica* has been figured), but recently D. C. Cooper (1935) has shown that in *Portulaca oleracea* the generative cell divides while the pollen grains are still in the anthers and I have observed the same in some sections of *Boerhaavia repanda* prepared by me this year (Figs. 52–54). Maheshwari has recently mentioned in a foot-note in Puri and Singh's paper on *Digera* (1935 ; p. 900) that three-nucleate pollen grains occur in *Boerhaavia diffusa* (see also his own paper, 1935 ; p. 602).
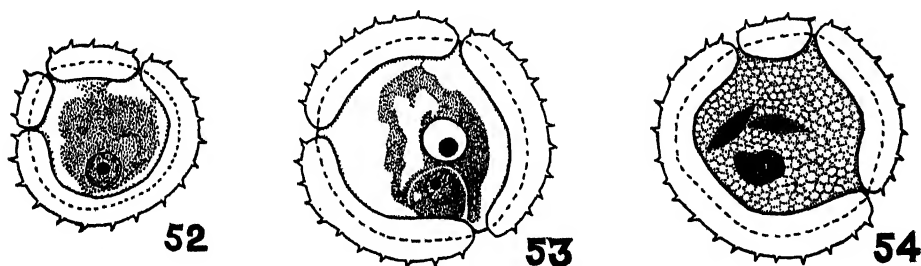


FIGS. 52–54.—*Boerhaavia repanda.* Stages in the development of the male gametophyte. ✕ 527.

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[3] The male cells shown in G. O. Cooper's figures of *Chenopodium album* (1935) are oval in outline and I believe they have been drawn from slightly earlier stages.

The general surface of the exine is granular and there are numerous germ pores regularly arranged all over (Fig. 50; see also Wodehouse, 1935; pp. 413–414).

It may be noted here that in sections of mature anthers, stained with safranin, crystal violet, small punctate discs, similar to those observed previously on the inner side of the tapetum, were also seen adjacent to the inner walls of the endothecial cells (Fig. 51).

In many pollen grains four nuclei were observed instead of the usual three. The actual division of the tube nucleus was not seen in my preparations, but stages like Figs. 45–48 leave no doubt that this does take place in some cases. As a parallel example one may cite the case of *Eichhornia crassipes* in which Smith (1896) found that one-half of the pollen grains examined by him showed two tube nuclei. Schürhoff confirmed this in 1922 and added that the two vegetative nuclei are formed as a result of a mitotic division. Recently, Juliano and Alcala (1935) have reviewed the literature in this connection and have themselves reported the occurrence of two to seven vegetative nuclei in *Musa errans* (Blanco) Teodoro var. *Botoan* Teodoro. In the family Chenopodiaceæ itself Billings (1934) found several four-celled pollen grains in *Atriplex hymenelytra,* but here the fourth cell is prothallial in nature. Recently P. C. Joshi (1936) has found a four-nucleate pollen grain in *Stellaria media.*

*The Ovule.*—The young ovule has the form of a conical elevation consisting of a mass of meristematic cells (Fig. 5). At first it grows slowly and evenly, but soon a more rapid growth on one side causes it to bend in the opposite direction. The two integuments now arise in rapid succession (Figs. 7, 8) and the ovule becomes completely inverted (Fig. 9). As development proceeds the curvature continues still further until it takes another turn through an angle of 90° as shown in Fig. 10. The integuments are each two layered (Fig. 55) but that part of the inner integument, which forms



**55**
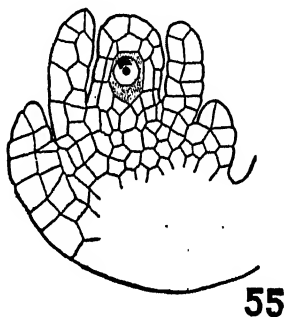
Fig. 55.—A longitudinal section of a young ovule at the megaspore mother cell stage showing the two integuments, each two-layered. × 214.

the micropyle, is thicker. In the chalazal region of the ovule, there is a prominent air space between the two integuments (Fig. 10). It has also been observed in *Pereskia amapola* var. *argentina* (Neumann, 1935) and in members of the families Basellaceæ and Portulacaceæ worked out by Rocén (1927).

*Megasporogenesis.*—The hypodermal archesporial cell in the young nucellus (Fig. 56) divides (Fig. 57) periclinally to form a primary wall cell and the megaspore mother cell (Fig. 58). Occasionally, two and three sporogenous cells (Figs. 59, 60) have also been observed but only one of them continues to develop further. Frequently, the megaspore mother cell is mounted on the top of an axial row of cells in the nucellus (Fig. 61) giving the false impression of a row of megaspores (see Joshi and Rao, 1934).

 The primary parietal cell undergoes one or two periclinal divisions to form a few wall layers, and the nucellar epidermis behaves similarly so that a massive nucellus is produced (Fig. 67) and the mature embryo sac may be buried below seven to eight layers of cells.

The megaspore mother cell increases in size and enters the usual synizesis stage (Fig. 61). After the first reduction division (Figs. 62, 63) a wall is laid down between the two nuclei (Fig. 64). The second division quickly follows and a linear tetrad of four megaspores is formed (Fig. 65). Normal megaspore tetrads have also been reported in *Chenopodium vulvaria* (Fischer, 1880), *Hablitzia tamnoides* (Dahlgren, 1916) and *Beta vulgaris* (Artschwager, 1927). In the last named plant, Oksijuk (1927) states that only three megaspores are formed and the same number was reported by Fischer (1880) in *Chenopodium fœtidum*.

The chalazal megaspore always functions and the upper three degenerate (Figs. 65). Further development is normal (see Figs. 66–69) and there are eight nuclei in the mature embryo sac (Fig. 69). The two polar nuclei fuse before fertilisation to form a prominent secondary nucleus which possesses a well-marked nucleolus and is always surrounded by starch grains. Rocén (1927) has noted the occurrence of starch grains in the mature embryo sacs of *Ullucus tuberosus*, a plant belonging to the allied family Basellaceæ. The synergids are hooked (Fig. 69) a feature which does not appear to have been noted previously in any plant of this family. There are three antipodal cells which usually disorganise at an early stage but in about half a dozen cases, they were found to be bi-nucleate (Fig. 70) even before fertilisation, although their number still remains the same. Oksijuk (1927) found four antipodal cells in *Beta vulgaris* in several cases and Artschwager and Starrett (1933) have confirmed this. In this respect, the family Chenopodiaceæ shows some
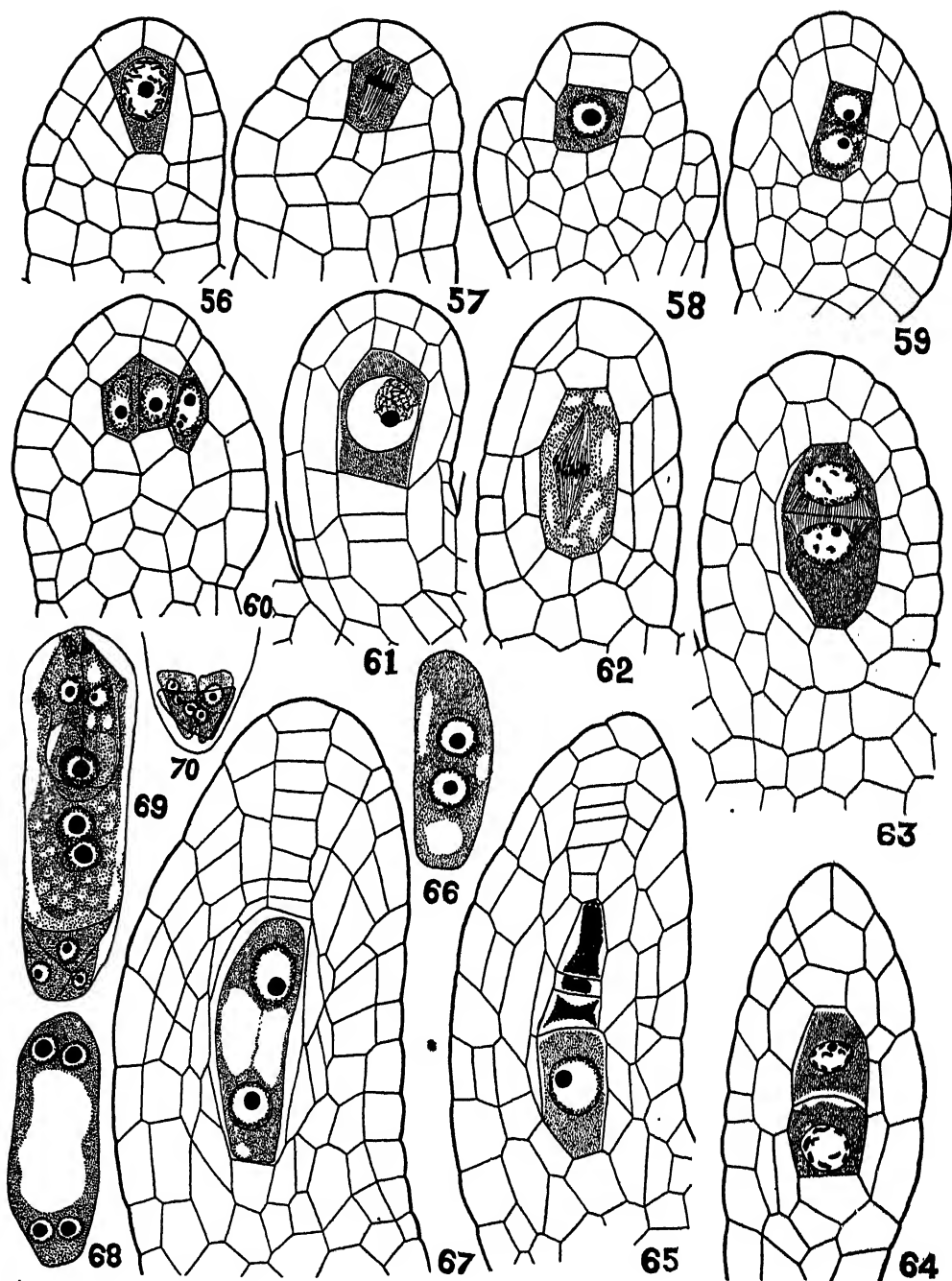
FIGS. 56–70.— × 774. Fig. 56.—L.S. nucellus with hypodermal archesporial cell. Fig. 57.—Same, in metaphase. Fig. 58.—A megaspore mother cell and primary wall cell. Fig. 59.—Two sporogenous cells lying one above the other. Fig. 60.—Three

resemblance to the family Nyctaginaceæ in which an increase in the number of antipodal cells has been observed in *Mirabilis jalapa, Oxybaphus viscosus* (Rocén, 1927), *Boerhaavia diffusa* (Maheshwari, 1929) and *B. repanda* (Bhargava, 1932). An embryo sac haustorium (cœcum) as has been reported by Oksijuk (1927) and Artschwager and Starrett (1933) in *Beta vulgaris* is absent in *Chenopodium album*.

The young embryo sac is at first straight, but soon the nucellar cells at the chalazal end begin to degenerate and it gradually assumes the form of a horse-shoe. Those cells of the nucellus, which are in a direct line with the micropyle become differentiated from others by being narrow and radially elongated (*cf. Beta vulgaris* ; Artschwager and Starrett, 1933). It is, through these cells, that the pollen tube will pass before entering the embryo sac.

| Ovule | Anther |
|---|---|
| 1. Hypodermal archesporial cell. | 1. No trace of the anther. |
| 2. Megaspore mother cell. | 2. Anther just differentiated. |
| 3. Megaspore mother cell in synizesis. | 3. Primary archesporial cells appear. |
| 4. Dyad stage. | 4. Primary wall layer cut off. |
| 5. Tetrad of megaspores. | 5. Endothecium, middle layer and tapetum become distinguishable. |
| 6. Two-nucleate embryo sac. | 6. Microspore mother cells in synizesis; tapetum bi-nucleate. |
| 7. Four-nucleate embryo sac. | 7. Microspore mother cells in reduction. |
| 8. Embryo sac with eight free nuclei. | 8. Microspores separated from one another. |
| 9. Mature embryo ac. | 9. Two-nucleate pollen grains ; one preparation showed only microspore mother cells at this time. |
| 10. Fertilised embryo sac with a globular embryo. | 10. Three-nucleate pollen grains. |

sporogenous cells lying side by side. Fig. 61.—Megaspore mother cell in synizesis. Fig. 62.—Same, metaphase of first reducing division. Fig. 63.—Same, in telophase. Fig. 64.—Dyad. Fig. 65.—Linear tetrad of four megaspores of which the upper three are degenerating. Fig. 66.—Young two-nucleate embryo sac. Fig. 67.— Same, advanced stage; nucellar epidermis has divided. Fig. 68.—Four-nucleate embryo sac. Fig. 69.—Mature eight-nucleate embryo sac. Fig. 70.—Lower portion of an embryo sac showing the three antipodal cells, two of which are bi-nucleate.

As mentioned before the flowers are strongly protogynous and the above table has been prepared to show the corresponding stages of development in the ovule and the anther.

*Endosperm.*—The primary endosperm nucleus divides much earlier than the fertilised egg and gives rise to a number of free nuclei (Fig. 73) which become specially numerous at the two ends of the embryo sac. When the cotyledons appear, wall formation starts in the micropylar region, and proceeds towards the chalazal end. Gradually the entire cavity of the embryo sac is filled with endosperm cells which are, however, soon absorbed by the growing embryo leaving only a single layer of cells at the micropylar end. A similar observation has been made by Artschwager (1927) in *Beta vulgaris.*
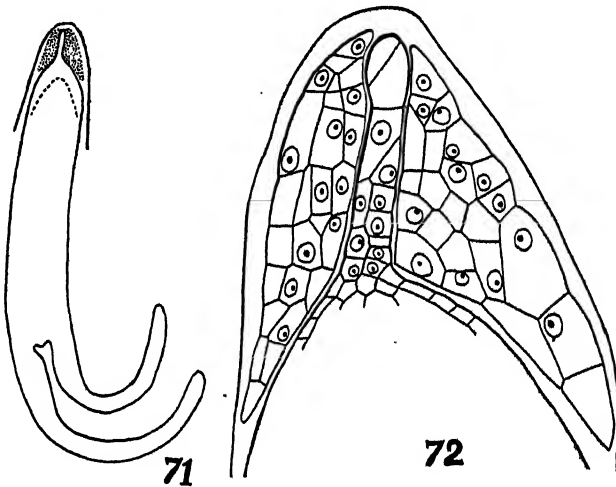


FIGS. 71–72.—*Boerhaavia repanda.* Fig. 71.—Diagram of an embryo with cap of endosperm cells at micropylar end. × 32. Fig. 72.—Same, upper part highly magnified. × 260.

The following chart summarises the condition of endosperm in the seeds of plants belonging to the order Centrospermales and shows the great similarity except in the case of the family Thelygonaceæ.

| Families | Early endosperm | Wall formation | Final stage | Region of food storage |
|---|---|---|---|---|
| CHENOPODIACEÆ<br>*Beta*<br>Oksijuk, 1927<br>Artschwager, 1927<br>Artschwager and<br>Starrett, 1933<br>*Chenopodium*<br>Bhargava, 1936 | Free nuclear | Starts at the micropylar end | A layer of cells over the tip of radicle | Perisperm |
| AMARANTHACEÆ<br>*Amaranthus*<br>Woodcock, 1931 | ,, | ,, | ,, | ,, |
| PHYTOLACCACEÆ<br>*Phytolacca*<br>Lewis, 1905<br>Woodcock, 1924<br>*Rivinia, Petiveria*<br>Mauritzon, 1934<br>*Gisekia*<br>Joshi and Rao, 1936 | ,, | According to Lewis walls are not laid down in the chalazal end. According to Woodcock walls are laid down throughout; same according to Mauritzon and Joshi and Rao | A cap of cells over the tip of the radicle | ,, |
| AIZOACEÆ<br>*Mesembrianthemum*<br>Huber, 1924<br>Schmid, 1925<br>Woodcock, 1931 | ,, | Starts at the micropylar end, later extends throughout | Present only as a cap of single layer of cells over the tip of the radicle | ,, |
| THELYGONACEÆ<br>*Thelygonium*<br>Woodcock, 1929 | Probably cellular from the beginning | .... | Cellular throughout | Endo-sperm |

| Families | Early endosperm | Wall formation | Final stage | Region of food storage |
|---|---|---|---|---|
| NYCTAGINACEÆ<br>*Mirabilis, Abronia*<br>   Rocén, 1927<br>*Mirabilis*<br>   Woodcock, 1928<br>*Boerhaavia*[4]<br>   Bhargava, 1936 | Free nuclear | Only in the micropylar region | A cap of vacuolate cells over the radicle | Perisperm |
| PORTULACACEÆ<br>*Claytonia*<br>   Woodcock, 1925<br>*Portulaca*<br>   Rocén, 1927 | ,, | Starts in the micropylar region | A single layer of distorted cells all round the embryo | ,, |
| BASELLACEÆ<br>*Basella*<br>   Rocén, 1927 | ,, | Walls are laid down in the whole region round the embryo sac | . . . . | ,, |
| CARYOPHYLLACEÆ<br>*Stellaria*<br>   Gibbs, 1907<br>*Alsine, Cerastium*<br>   Woodcock, 1926 ; 1927<br>*Herniaria, Polycarpon,*etc.<br>   Rocén, 1927 | ,, | Wall formation varies in different cases | A cap of cells over the tip of the radicle | ,, |
| CACTACEÆ<br>*Rhipsalis*<br>   Mauritzon, 1934 | ,, | . . . . | . . . . | ,, |

*Embryo.*—Fig. 74 shows a four-celled proembryo which has evidently arisen by transverse divisions of the oospore. Fig. 75 shows a filamentous proembryo with eight cells. Vertical divisions have started at the stage shown in Fig. 76. A little later the embryo becomes globular by a few more transverse and longitudinal divisions in the apical cells. Fig. 77 shows a more advanced stage where the two cotyledons have been marked out and

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[4] In my original paper on *Boerhaavia repanda* (1932), I did not make any mention of this fact. Walls are laid down in this case also only in the micropylar region and in the mature seed a cap of vacuolated cells over the radicle (Figs. 71, 72) is present and perisperm is the region of food storage.

the suspensor cells have divided by vertical walls making it massive. A similar suspensor is found in *Chenopodium Bonus-Henricus* (Souéges, 1920) and *Beta vulgaris* (Artschwager, 1927). On the contrary, a characteristically linear suspensor is present in *Kochia scoparia* (Williams, 1932). Dahlgren (1916; p. 70) writes, "Der suspensor besteht wenigstens bei *Atriplex hortensis* L. (Cohn, a.a. O. Fig., 19) und *Chenopodium viride* (= *C. album* L. ?) (Meyen, 1841, S. 227) nicht aus einer einzigen Zellreihe."
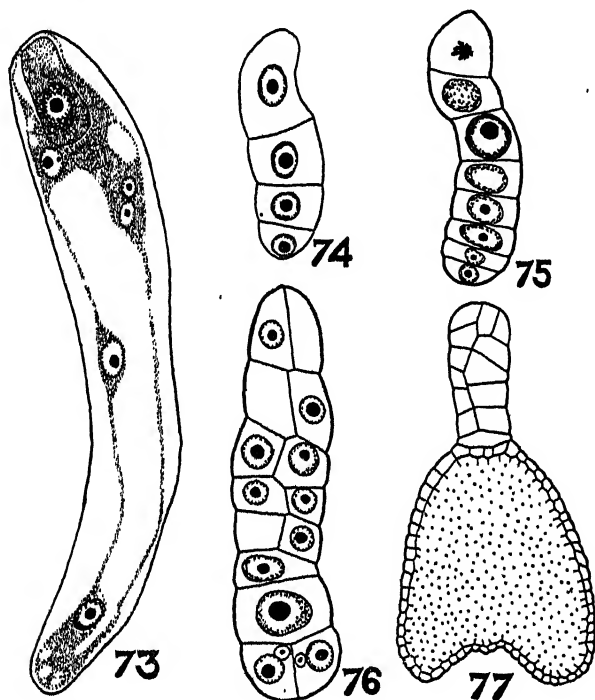


FIG. 73.—Fertilised embryo-sac showing the undivided egg and several free endosperm nuclei. $\times$ 574.

FIGS. 74–76.—Stages in the development of the proembryo. $\times$ 574.

FIG. 77.—Older embryo with the two cotyledons now marked out. $\times$ 214.

Oksijuk (1927) in his study of *Beta vulgaris* states that the basal cell of the two-celled proembryo does not take part in the formation of the embryo, but that it enlarges and assumes the character of a haustorial cell. In *Chenopodium album* the basal cell divides and does not take the rôle of a haustorial cell.

The mature embryo is curved like a horse-shoe as in *Beta vulgaris* (Oksijuk, 1927; Artschwager, 1927; Artschwager and Starrett, 1933) and *Kochia scoparia* (Williams, 1932). Considerable quantities of starch are stored in

the perisperm. The integuments also undergo some changes the most conspicuous of which is the deposition of tannin. At first the cells of the outer integument are all alike but those of the outer layer enlarge early and become radially elongated while their nuclei degenerate. The walls begin to thicken and a very thick cuticle differentiates on the outside. The cells of the outer layer of the inner integument remain small, gradually lose their contents and ultimately disappear. The inner layer continues to persist till the end (Fig. 78). As in *Kochia scoparia* (Williams, 1932), the perianth is retained round the fruit at maturity. The outer surface of the former is covered with uniseriate glandular hairs (Fig. 79). These also occur on the inflorescence axis. Similar glandular hairs have also been seen in *Boerhaavia diffusa* (Maheshwari, 1929).
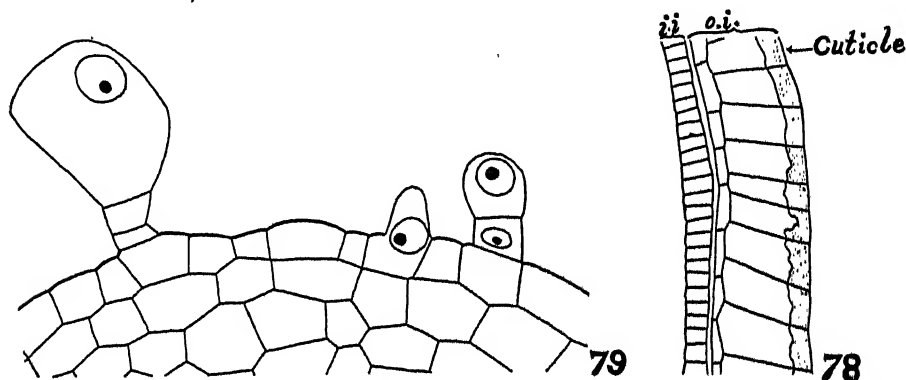


FIG. 78.—Longitudinal section of a part of the seed coat. *i.i.*, Inner integument; *o.i.*, Outer integument. $\times$ 574.

FIG. 79.—Longitudinal section of the perianth showing the grandular hairs. $\times$ 774.

## Summary.

1.  The floral parts develop in acropetal succession. There is only one whorl of perianth. The gynæceum consists of two carpels containing a single ovule.

2.  Each of the perianth lobes and the stamens receives a single vascular bundle and a single vascular bundle enters the ovary which directly supplies the ovule. No vascular bundle is found in the ovary wall.

3.  The development of the anthers lags behind that of the ovary. There are three wall layers below the epidermis—the endothecium, an ephemeral middle layer and the tapetum. The cells of the last become two- to four-nucleate by mitotic divisions. The divisions of the microspore mother cells are simultaneous. Cytokinesis occurs by furrowing. The arrangement of the microspores may be either tetrahedral or isobilateral. The tapetal cells enter inside the anther loculus after the microspores have separated.

4. The pollen grains are three-celled at the time of shedding. In some cases two vegetative nuclei were seen—a condition evidently brought about by the division of the tube nucleus. Occasionally, pollen grains with naked male nuclei are also present.

5. The ovules have two integuments each of which is two cells thick except the inner which is thicker at the top.

6. Usually there is a single hypodermal archesporial cell in the nucellus which divides to form the primary wall cell and the megaspore mother cell. Sometimes two and three such cells were also seen. The nucellar epidermis and the primary wall cell both divide to form the wall tissue.

7. A normal tetrad of four megaspores is formed of which the chalazal functions and gives rise to an embryo sac of the usual eight-nucleate type. The synergids are hooked. Occasionally the antipodal cells become bi-nucleate.

8. The endosperm is free nuclear. Wall formation starts at the micropylar end. In the mature seed only a single layer of endosperm cells remains just above the radicle. The storage tissue is the starchy perisperm.

9. The zygote undergoes several transverse divisions and a filamentous proembryo is formed. The suspensor becomes long and massive and consists of at least two cell rows. The mature embryo is curved like a horse-shoe.

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# ANTAGONISM IN FUNGI AS A MEASURE OF CONTROL IN 'RED-LEG' DISEASE OF LETTUCE.*

BY R. P. ASTHANA, M.Sc., D.I.C., PH.D.

(*From the Department of Botany, Agra College, Agra.*)

## I. *Introductory.*

IN a study of the so-called "Red-leg" disease of lettuce caused by *Botrytis cinerea*, Salam[9] concluded that the fungus is present in the dead leaf bases of seedlings at the time the latter are transplanted from the frames to the open ground in early spring. The process of transplanting combined with changes in the conditions of growth—in particular cold wet conditions in the open ground—apparently weakens temporarily the resistance of the plants so that many of these succumb to the disease.

Earlier it had been shown by Vasudeva[10] that the activity of certain fungi parasitic on apple was markedly reduced by the presence of another organism.

The object of this investigation was to find whether the parasitic vigour of *Botrytis cinerea* on lettuce could be similarly influenced. If that were possible it would not be a difficult operation to spray the plants in the frames with a spore suspension of the contaminating fungus, and thereby check the growth of the parasite for the time being. Such a fungus, if it could be found, would require to be of a readily sporulating type and also one which grew freely at rather low temperatures.

The following is an account of work carried out with the object of discovering such a fungus.

## II. *Historical.*

The retarding action of one fungus upon another in artificial culture has been described by a number of workers, *e.g.*, Potter,[8] Brown,[1] Porter.[6,7]

As regards the effect of one organism upon the parasitic vigour of another, the following are the more important references.

Fawcett[3] showed that the attack of *Pythiacystis citrophthora* was increased by adding a species of *Fusarium* to the inoculum.

Brooks and Moore[2] state that cut surfaces of plum wood, which have become invaded by miscellaneous air-borne fungi, are thereby rendered incapable of infection by the spores of *Stereum purpureum*.

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* The investigation was carried on in the Plant Pathology Laboratory of the Imperial College of Science and Technology, London.

Millard and Taylor[5] found that the presence of saprophytic *Actinomyces* markedly reduces the attack of the potato scab organism, and that the reduction was the greater the more favourable the conditions were for the growth of the saprophyte.

Vasudeva (*loc. cit.*) found that the rate of invasion of apple fruit by *Monilia fructigena, Botrytis cinerea, Sphæropsis malorum* and *Penicillium* sp. was markedly reduced by the presence in the inoculum of such non-parasitic fungi as *Botrytis Allii, Fusarium cæruleum, Cunninghamella elegans, Helminthosporium Maydis* and *Actinomyces tricolor.* Even, when *B. cinerea*, which is in itself parasitic to apple fruit, is added to *Monilia fructigena*, the attack of the latter is thereby reduced. Vasudeva was able to show, in the case of *Botrytis Allii* that the retarding effect of this fungus could be reproduced by an aqueous extract of its hyphæ. The effect was thus reducible to the staling effect of one organism upon another.

Leemann[4] found that the resistance of wheat seedlings to *Helminthosporium sativum* was modified by the addition to the soil of extracts of certain fungi and bacteria, in some cases an increase, in others a decrease of parasitism taking place. He interpreted these results as indicating a change in susceptibility of the host due to the uptake of certain fungal or bacterial products from the soil.

### III. Experimental.

(*a*) *Material and method.*—Altogether fourteen organisms were tested in this work. These were obtained from the stock cultures kept in the Plant Pathology and Bacteriology Departments of the Imperial College of Science and Technology, London. The list is as follows :—

> *Cunninghamella elegans*
> *Aspergillus niger*
> *Aspergillus flavus*
> *Eurotium herbariorum*
> *Penicillium chrysogenum*
> *Trichoderma lignorum*
> *Eidamia viridescens = Trichoderma viridescens*
> *Hormodendron* sp.
> *Fusarium fructigenum*
> *Botrytis Allii*
> *Phoma* sp.
> *Sclerotinia fructicola*
> *Bacillus megatherium*
> An unidentified *bacterium.*

All the cultures were maintained on 3% malt agar at room temperature

(15°–20° C.). The spores required for inoculation purposes were taken from cultures seven to ten days old.

"Trocadero" cabbage lettuce seedlings were mainly used for the infection experiments. The leaves were taken from seedlings which were 4 to 6 weeks old, but sometimes, leaves from older seedlings, 10 to 12 weeks old, were also used. For inoculation purposes, the leaves, which had been washed and sterilised by 0·1% mercuric chloride, were kept in moist Petri dishes.

Lettuce agar was the basal medium for the preliminary work. It consisted of starch 1%, lettuce extract 20% and agar 1·5%. The lettuce extract was obtained by steaming the lettuce leaves for two hours and then squeezing out the juice. The extract thus obtained, which was of full strength, was filtered, autoclaved and stored for the experimental work. Very often 3% malt with or without agar was also used.

A mixed inoculum was placed on one half side of a leaf and on the other side, by way of control, an inoculum of *B. cinerea* spores alone. By this means the error due to varying susceptibility of different leaves was largely avoided. To further standardise the method, 0·1 c.c. of spores of *Botrytis cinerea* (seven to ten days old) was obtained by centrifuging under sterile conditions and to these 25 c.c. of water or of the required solution was added. The spore suspensions of the other fungi were similarly standardised.

Any other detail of the methods employed will be given at their appropriate places.

(b) *Effect of various organisms upon the germination and growth of* B. cinerea *in culture.*—In one series of experiments, inocula of *Botrytis cinerea* and of the various fungi listed above were placed two centimetres apart on plates of lettuce agar and incubated at 15° C. for one week. It was found that in the majority of cases the *B. cinerea* spread over the plate and overgrew the neighbouring colony confining it to a small area around the inoculum. The following seven fungi, *Penicillium chrysogenum, Cunninghamella elegans, Hormodendron* sp., *Aspergillus flavus, Eidamia viridescens, Phoma* sp., *Trichoderma lignorum*, and the unidentified *bacterium* definitely checked the growth of the *Botrytis cinerea* and prevented its spread over the plate.

Experiments at 10° C. showed that the growth of *B. cinerea* was only inhibited by four of the eight organisms, *Penicillium chrysogenum, Eidamia viridescens, Phoma* sp., and *Trichoderma lignorum*. The rate of growth of the others at this temperature was so much slower than that of *B. cinerea* that the latter spread over the plates.

The same results were obtained when mixed inocula of *B. cinerea* spores and those of the above fungi were sown in the centre of plates of lettuce agar which were incubated at 15° C. After a week, growth of *B. cinerea*

had spread over all the plates except those in which *P. chrysogenum, E. viridescens, Phoma* sp., and *T. lignorum* had been mixed with *Botrytis* inoculum. A slight retardation was shown by *Cunninghamella elegans, Hormodendron* sp., *A. flavus*, and the unidentified *bacterium*, and none of the remainder.

The eight organisms which showed a tendency to inhibit the growth of *B. cinerea* in the above experiments were grown on lettuce agar plates for one week at 15° C. After that period the solid medium of the plates was turned upside down so that the bacterial or fungal colony was underneath. This medium was now inoculated by *B. cinerea* at the top and incubated for six days. There was only a scanty mycelial growth and sporulation of *Botrytis cinerea* in the cultures with *P. chrysogenum, E. viridescens, Phoma* sp. and *T. lignorum* but it was profuse with the other organisms.

The preceding experiments agree in showing that, from the point of view of the problem in question, the four potentially useful fungi are :—

> *Penicillium chrysogenum*
> *E. viridescens*
> *T. lignorum*
> *Phoma* sp.

(c) *The influence of certain fungi on the attack of lettuce by* B. cinerea.— The effect of including spores of other fungi in the inocula of *Botrytis cinerea* is shown in Tables I and II. The figures in the tables give the average areas

TABLE I.

| Active fungus | | Amount of rot | Mixed inoculation | | Amount of rot |
|---|---|---|---|---|---|
| *B. cinerea* | .. | 3·4 sq. cm. | *B. cinerea* +<br>P. chrysogenum | .. | 1·2 sq. cm. |
| ,, | .. | 3·9 ,, | *B. cinerea* +<br>E. viridescens | .. | 1·5 ,, |
| ,, | .. | 3·2 ,, | *B. cinerea* +<br>T. lignorum | .. | 0·6 ,, |
| ,, | .. | 3·6 ,, | *B. cinerea* + *Phoma* sp. | | 0·8 ,, |

TABLE II.

| Active fungus | | Amount of rot | Mixed inoculation | | Amount of rot |
|---|---|---|---|---|---|
| *B. cinerea* | .. | 2·1 sq. cm. | *B. cinerea* +<br>P. chrysogenum | .. | 0·6 sq. cm. |
| ,, | .. | 1·9 ,, | *B. cinerea* +<br>E. viridescens | .. | 0·8 ,, |
| ,, | .. | 1·6 ,, | *B. cinerea* +<br>T. lignorum | .. | 0·35 ,, |
| ,, | .. | 1·8 ,, | *B. cinerea* + *Phoma* sp. | | 0·5 ,, |

of the lesions produced in 8 days, ten leaves being used in each case. In these experiments the spores were sown in water. The leaves used in Table I were taken from seedlings grown for 4 to 6 weeks in boxes in the open and sown early in April; those in Table II from glass frames (10 to 12 weeks old) sown in early February.

From these tables it is seen that the two fungi most active in reducing the attack of *Botrytis cinerea* are *T. lignorum* and *Phoma* sp.

A comparison of the results obtained when spores are sown in (a) water, (b) full concentration of lettuce extract, (c) 3% malt, is given in Table III.

TABLE III.

| Medium | Active fungus | Amount of rot | Mixed inoculation | Amount of rot in sq. cm. | % of rot |
|---|---|---|---|---|---|
| Water | *B. cinerea* | 0·4 sq. cm. | *B. cinerea* + *P. chrysogenum* | 0·33 | 82·5 |
| | ,, | 0·52 ,, | *B. cinerea* + *E. viridescens* | 0·12 | 23 |
| | ,, | 0·48 ,, | *B. cinerea* + *T. lignorum* | 0·1 | 28 |
| | ,, | 0·35 ,, | *B. cinerea* + *Phoma* sp. | 0·08 | 17 |
| Lettuce Extract 100% | ,, | 0·43 ,, | *B. cinerea* + *P. chrysogenum* | 0·13 | 30 |
| | ,, | 0·38 ,, | *B. cinerea* + *E. viridescens* | 0·06 | 16 |
| | ,, | 0·32 ,, | *B. cinerea* + *T. lignorum* | 0·05 | 11 |
| | ,, | 0·45 ,, | *B. cinerea* + *Phoma* sp. | 0·03 | 9·4 |
| 3% Malt | ,, | 0·64 ,, | *B. cinerea* + *P. chrysogenum* | 0·8 | 125 |
| | ,, | 0·57 ,, | *B. cinerea* + *E. viridescens* | 0·02 | 3·6 |
| | ,, | 0·79 ,, | *B. cinerea* + *T. lignorum* | 0·04 | 4 |
| | ,, | 0·96 ,, | *B. cinerea* + *Phoma* sp. | 0·01 | 1·2 |

The data refer to the area of the lesions produced in 4 days on the leaves from 4 to 6 weeks old seedlings.

The last column gives the percentage of attack by the mixed inocula in relation to that of *Botrytis cinerea* alone.

Here again it is seen that *Trichoderma lignorum* and *Phoma* sp. were the most active in reducing the attack of *B. cinerea* and that they are fully more effective when sowings are made in nutrient than in water. It is noticeable that in one case (*B. cinerea* + *P. chrysogenum*) on 3% malt the mixed inoculum produced more attack than did the pure culture of the parasite.

(d) *Influence of certain fungal extracts on attack of lettuce by* Botrytis cinerea.—Cultures of *Penicillium chrysogenum*, *E. viridescens*, *Trichoderma lignorum* and *Phoma* sp. were set up in flasks on 3% malt, and after one week's growth the liquid was filtered under sterile conditions and kept at 55° C. for six hours to kill any spores present. Ten c.c of each filtrate was taken and to it one c.c. of the standard water suspension of *B. cinerea* spores was added. Similar sowings in 3% malt solution served as controls. The leaves from 4 to 6 weeks old seedlings were inoculated by one drop of such a spore suspension and incubated at 15° C. for 4 days. Table IV gives the average area of rot of twenty-five inoculations in malt and in the fungal filtrates.

TABLE IV.

| Active fungus in 3% malt | Amount of rot | Active fungus in stale medium | Amount of rot in sq. cm. | % of rot |
|---|---|---|---|---|
| B. cinerea    .. | 0·46 sq. cm. | B. cinerea + filtr. of P. chrysogenum | 0·2 | 44 |
| ,,    .. | 0·5    ,, | B. cinerea + filtr. of E. viridescens | 0·06 | 12 |
| ,,    .. | 0·54    ,, | B. cinerea + filtr. of T. lignorum | 0·02 | 3·7 |
| ,,    .. | 0·4    ,, | B. cinerea + filtr. of Phoma sp. | 0·01 | 2·5 |

It is seen from the above table that the stale filtrates behave in the same manner as the fungi themselves in reducing the attack of *Botrytis cinerea* on lettuce leaves, thus suggesting that the action is due to the staling products.

## IV. Summary.

(1) A number of fungi have been tested with respect to their repressing effect on the germination, growth and parasitic vigour of *Botrytis cinerea*. The most active fungi in these respects were : *Penicillium chrysogenum, Eidamia viridescens, Trichoderma lignorum* and *Phoma* sp., the two last particularly.

(2) The same effect is produced by filtrates of the medium in which these fungi have grown, thus suggesting that the action is due to staling products.

The writer wishes to express his sincere thanks to Professor W. Brown, of the Imperial College of Science and Technology, London, under whose able guidance and suggestion this investigation was carried out.

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# THE DECCAN TRAPS.

By L. Rama Rao.

*(Department of Geology, Central College, Bangalore.)*

## Introduction.

A PERUSAL of the several papers published from time to time dealing with the Deccan traps of India shows that this extensive rock-formation offers many problems of great interest and importance in the geological history of India. The object of this paper is to review briefly our present knowledge of these rocks and offer a new interpretation of their mode of accumulation and geological history—an interpretation which if it does nothing more, may at least serve to stimulate and provoke further thought and discussion on lines leading to a satisfactory solution of the many knotty problems connected with this great volcanic rock-formation.

## Some facts about the Deccan Traps.

Let us recapitulate at the outset some of the main facts about the Deccan traps which have been definitely established. These may be briefly summarised as follows :—

(1) They are the result of the accumulation of subaerial lava flows of the nature of fissure eruptions.

(2) They extend through about 10° of latitude and 15° of longitude, thus covering an enormous area of not less than 200,000 sq. miles at the present day.

(3) The maximum thickness of the formation near Bombay is about 7,000 feet or more ; the average thickness, considering the entire area being about 2,000 feet. The actual thickness, however, varies from place to place, being in some cases as low as about 100 ft.

(4) The individual flows making up the total thickness in any given locality, are comparatively thin—their average thickness being only about 40–80 feet.

(5) These lava flows show an almost persistent horizontality practically throughout their area, the minor exceptions to this rule being easily proved as due to local and minor post-trappean disturbances.

(6) Associated with these lava flows in some areas are noticed several volcanic ash beds, which appear and gradually become more frequent in the upper half of the entire formation.

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(7)   Intercalated between some of these lava flows are a few distinctly sedimentary fossiliferous beds—the inter-trappeans—usually of freshwater origin.   These inter-trappean beds are confined either to the lowermost or to the uppermost portions of the formation, the middle portion which forms more than two-thirds of the total thickness being entirely devoid of them.

(8)   What we now see of the Deccan traps is only a remnant of the original formation, after the removal of a large part by subaerial denudation acting during the long period of time  during which these lava flows have been in existence.

While these facts of observation have been generally accepted, there are certain other aspects of the formation about which there has been some difference of opinion ; and it is proposed to discuss a few of these in the course of this paper.   In such a discussion, it is useful to remember that the Deccan traps of India are only one of several other similar fissure eruptions occurring in various other parts of the earth at about the same period of time. This will enable us to take a wider outlook and realise our kinship with similar geological problems elsewhere.

It has been generally accepted that these lava flows are of the nature of fissure eruptions where the emission of lava is a comparatively quiet process. Though it is true that the occurrence of ash beds locally interrupting these lava flows indicate a certain amount of explosive violence now and then, yet it must be admitted that such explosive phenomena are only local and temporary, and do not vitiate the truth of the general proposition that these lavas have issued quietly from fissures.  Considering the volume of lava that has been thrown out and the wide area which it covers,  one  would expect the existence of a large number of these feeding fissures scattered all over, which we would now expect to see as long and narrow dykes, especially in the peripheral tracts of the present trap area ; and such indications of former vents have been noticed in some areas.

There is no doubt that the opening of these fissures must be connected with the intense diastrophism associated with the disruption of the Gondwana continent.   As Joly[1] says : "It was at or near the close of the cretaceous and dawn of the eocene that this great continent (named by Suess Gondwanaland) broke up and as a continent disappeared. This event was, so far as we know, synchronous with the overwhelming of peninsular India by a mile deep covering of the basaltic substratum.   And further, it is believed that the diastrophism in Gondwanaland was connected with the movements which led to the outflow of the Deccan ; for the fissures which emitted the lava had the same

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[1] Joly, *The Surface History of the Earth,* 1925, p. 135.

east to west trend as ancient faults which traversed the northern part of Gond-
wanaland and along which the later movements were directed." It is now
generally recognised that the disruption of the Gondwana continent took
place in stages, somewhat as follows : The connection between Australia
and India (united with Madagascar and South Africa) disappeared soon after
the jurassic period ; the connection between South America and Africa dis-
appeared in the lower to middle cretaceous ; and the connection between
India and Madagascar (the Lemurian bridge) broke down at the beginning of
the tertiary. It is this last stage in the disruption that we have to remember
in connection with the Deccan lava flows. It has been customary to think
that this land connection extended right across the present Arabian Sea
connecting Western India with Abyssinia and Somaliland. But the recent
observations of Dr. Fox[2] on the Abyssinian lavas of Magdalla and Ashiangi
show that they never extended as far east as Aden and certainly did not
cover the Somali peninsula ; and so these lavas can have nothing to do with
the Deccan traps of India. Thus, it is altogether unlikely that the Deccan
traps cover much of the floor of the present Arabian Sea. According to
Dr. Fox, "the region of Somaliland and Southern Arabia was open sea in upper
cretaceous and early tertiary times, while the region to the west was land in
that geological period. I think a great bay connecting with an open sea
to the north lay over the northern part of the present Arabian Sea in late
cretaceous and early eocene time." At the time of the first eruption of the
Deccan lavas, therefore, the land probably extended only southwest of
Bombay as a land bridge connecting India with Madagascar, to the north
and west of which lay an arm of the Northern Sea. The first effect of the
disturbances which led to the foundering of this land connection, must have
been the formation of numerous fissures all over the area. These fissures
were doubtless due to tensile forces which must naturally originate, according
to Joly[3] as a result of the fusion of the basaltic substratum below. The
actual mechanics of the rise of basic magmas along such through-striking
fissures has been discussed by Bucher,[4] and he comes to the conclusion that
" the same stresses which create the relief of pressure along fracture lines
(by a pulling apart of the resisting crust) also furnish the driving power that
carries the heavy liquid up into the light crust." When once these fractures
and fissures have been established through which the lavas begin to flow out,
the question to consider is, did they simply flow out all over the area

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[2] Kindly conveyed to me in the course of a recent letter, for which I am greatly indebted
to him.

[3] Joly, *The Surface History of the Earth*, 1925, p. 94.

[4] Bucher, *The Deformation of the Earth's Crust*, 1933. p. 272.

simultaneously and continuously for some time and then stop ; or did they come out in stages, periods of eruptive activity alternating with periods of quiescence ?   In other words, we have now to consider the history and duration of this eruptive activity.

### Duration of Eruption.

This question regarding the duration in time represented by these Deccan eruptions is a very important one, not only in itself but also because of its bearing on another very interesting question—the age of the Deccan traps.   On this point regarding the duration of the Deccan trap period, W. T. Blanford wrote as follows[5] so far back as 1867 : "Those who have fully appreciated the gradual conviction which has of late years been forced upon the minds of most field geologists of the enormous periods of time which have been necessary for the accumulation of the various rock masses forming the earth's crust will have no difficulty in understanding that a large division, even of geological time, may very probably have elapsed during the accumulation of the Deccan traps.   The thickness of these beds cannot be much less than 5,000 feet ; perhaps it is considerably more. * * * That long intervals of time, in some cases at least, elapsed between the different lava flows of which this enormous thickness is composed, is shown by the local accumulation of freshwater deposits abounding in remains of animals and plants.   In each of these cases a lake must have been formed, and have become tenanted by a large number of different species of mollusca, etc.—a very slow process.   In some places, near Baroda, I met with large accumulations of rounded pebbles not only of metamorphic and sedimentary rocks but of the trap itself, intercalated between beds of basalt and amygdaloid, so that denudation must have taken place to a considerable extent in the intervals between successive flows."   Thus Blanford has mentioned three important considerations, the full implications of which we must recognise, indicating that a very long period of time must have elapsed between the beginning and close of the volcanic period.   Add to these the fact that we frequently come across, between some of these trap flows, layers of red clay or bole which are due to the atmospheric disintegration of the surface of the basalt on which it rests before the eruption of the overlying flow.   As Geikie has pointed out[6] these layers must be looked upon as "furnishing evidence of the lapse of an interval sufficiently extended to permit a considerable subaerial decay of the surface of a lava sheet before the flow of the next lava".   And then also there is

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[5] W. T. Blanford, "Traps of Western and Central India," *Mem. Geo. Sur. Ind.,* 1867, 6, Pt. 2, p. 147.

[6] A. Geikie, *Ancient Volcanoes of Great Britain,* 1897, Vol. II, p. 204.

the pronounced difference in the nature of the fossil fauna and flora found in the inter-trappean beds at the base of the formation near Nagpur and those at the top near Bombay.   The latter are decidedly much more highly evolved than the former and such evolutionary changes necessarily require quite a long period of time.   In view of these considerations we have to conclude that "these outflows did not always rapidly follow each other but were separated by intervals of varying, sometimes even of longer duration"; or to quote Iddings[7] we must realise that "not one burst but repeated flows through long ages have built the plateau of the Deccan".

### Geological history of the Deccan Trap period.

We know that from very early times the Deccan traps have been classified as follows[8]:

|  |  | *Min. thickness.* |
|---|---|---|
| *Upper traps* | (with numerous beds of volcanic ash and the inter-trappean sedimentary beds of Bombay) | 1,500 ft. |
| *Middle traps* | (ash beds numerous above but less frequent towards the base; no sedimentary beds known) .. .. .. .. | 4,000 ft. |
| *Lower traps* | (with inter-trappeans of Nagpur, Narbada valley, etc.  Ash beds of rare occurrence or wanting) .. .. .. .. | 500 ft. |

The general geological conditions during the period of the Deccan trap eruptions have been nicely pictured to us by W. T. Blanford[9] when he says: "When first lava flows are poured over the irregular surface of a country shaped by subaerial denudation, as the surface of India appears to have been shaped before the first volcanic outbursts, hollows must be filled up and rivers dammed, so that shallow lakes will be formed.   These will not, in all probability, be of any large size.   Fresh flows of lava will fill up the first lakes, but by damming up other hollows, will produce new ones, and so on until by the constant accumulation of volcanic material the land has either been reduced to a plane or the intervals between different lava flows are too short to allow of the accumulation of sedimentary deposits.   It is even possible that the region may have become barren and desolate, unfitted for organic existence. * * *   It is in any case easy to understand that when rest from volcanic disturbances, showers of ash and lava flows permitted sedimentary

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[7] J. P. Iddings, *The Problem of Volcanism*, 1914, p. 22.

[8] Medlicott and Blanford, *A Manual of the Geology of India*, 1879, Pt. 1, p. 308.

[9] W. T. Blanford, "Traps of Western and Central India," *Mem. Geo. Sur. Ind.*, 1867, 6, Pt. 2, pp. 155–156.

deposits again to accumulate in the intervals between eruptions, the old lacustrine fauna of the district had died out, and the change had taken place, which is indicated by the fossils of the Bombay inter-trappeans. It is also in accordance with probability, I think, to suppose that the volcanic energy was less, the flows more partial, and the periods of intermission longer, at the commencement and towards the close of the trap epoch than in the middle of the period." While this description is no doubt generally true, recent and more detailed studies of the Deccan traps seem to show that the geological history of the area during this period was not so simple as all this. Before proceeding to consider what it must have been, let us remember some more facts which have got to be explained.

There is first of all the general horizontality of the traps, over large areas. While there is no doubt that this is partly due to the highly fluid nature of the basaltic lavas which issued from the fissures, yet this cannot offer the full explanation. The lava flows cover thousands of square miles at the present day; immediately after extrusion, they must have occupied a much larger area. Practically throughout this area the lavas show a strikingly horizontal disposition. While it is true that basaltic lavas are highly fluid, it is also true that the distance through which a given flow will travel from the fissure can hardly exceed more than about 50–60 miles on horizontal or even gently sloping ground. So to explain the horizontal disposition of the traps over such a large area, we have to grant the existence of an exceedingly large number of feeding fissures in close proximity to one another, even at the commencement of the trappean period. If so all these fissures would naturally have been filled up by the consolidated lava later on and be left behind as dykes; and at the present day, after denudation, we should have seen these dykes in large numbers, especially in the country just outside the present margin of the trap area, as in the case of the tertiary fissure eruptions near Mount Stuart, Washington.[10] And then again a satisfactory solution of this problem of the horizontality of the traps must naturally involve a consideration of the exact nature of the floor on which the first lava flows accumulated. Some opinions have been already expressed[11] about the character of the pre-trappean surface in certain areas; but these have only a local significance and do not deal with the entire formation as a whole. To the present writer, it appears that a satisfactory explanation of this horizontality and all the other known

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[10] R. A. Daly, *Igneous Rocks and the Depths of the Earth*, 1933, p. 140.

[11] Medlicott and Blanford, *A Manual of the Geology of India*, 1879, Pt. 1, p. 323; L. L. Fermor and C. S. Fox, "The Deccan Trap Flows of Linga, Chhindwara Dt., C.P.," *Rec. Geo. Sur. Ind.*, 1916, **47**, Pt. 2, pp. 88–89.

facts regarding the entire Deccan trap formation will be facilitated on the basis of an altogether different conception of the geological history of the trappean area.

It is generally accepted that at the beginning of the trappean period, a part of Gondwanaland still existed on the southwestern side connecting India with Madagascar. Thus the Deccan eruptions of lava covered not only a large part of peninsular India but must have also extended over quite a large area of this land to the southwest of the present coast line. This extensive area of eruptive activity appears to have been generally in the form of a broad, shallow, (probably saucer like) depression, more or less oval in outline with its longer axis roughly NE–SW. Of course the sides and bottom of this depressed area were not so smooth and regular as in the case of the analogy suggested, but were highly irregular, being composed of a number of more or less gently undulating ups and downs, with several lines of drainage determined by the irregularities of denudation necessarily present on such an ancient land area ; and it is presumed that the first fissures were split open on the floor of such a basin. We must however remember that, as Dr. Fox[12] has pointed out, the outpourings of lava for the various flows did not come from one particular locality but that fresh centres were chosen in most cases ; and that these centres "probably began in the east and gradually shifted to the west with, of course, some irregularities. In consequence of such local variations, there is found to be a certain amount of overlapping of the flows." Under these circumstances, with the continual emission of highly fluid lava— almost as thin as water, according to Iddings—from these fissures, the lavas will flow out, fill up all the minor depressions and thus ultimately tend to fill the entire basin from below upwards covering all the irregularities in this process ; and with the lavas highly fluid and mobile, they would naturally at all stages of this filling up show a more or less level surface. Further, when the basin is thus filled up by the consolidated lava, the main vents themselves through which the lavas came out would be covered up by the entire thickness of the lava flows above, thus concealing them from view altogether. Thus though fed only by a few vents on the floor of the basin, the highly liquid lavas would gradually extend out and cover more and more of the outer regions of the basin till at last the entire basin is filled up and the area becomes more or less a flat plain of lava. It would thus be possible to see along the peripheral regions, for instance, of such an area quite a thick series of lava flows, without any actual vent being noticeable below. These eruptions were frequently interrupted locally by long periods of quiescence

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[12] C. S. Fox, "Possibilities of finding coal-field at a workable depth in Bombay Presidency," *Rec. Geo. Sur, Ind.,* 1926, 58, Pt. 2, p..90,

affording opportunities, as Blanford has pointed out, for the deposition of freshwater sediments, now seen as inter-trappean beds. These first lava flows are what we now recognise as the lower traps.

Then there appears to have been a pause in the eruptive activity. During this period, certain minor disturbances seem to have occurred in parts of this area producing a certain amount of gentle folding and faulting among these lava sheets, as is evidenced by the observations of Fermor and Fox[13] in the Linga area, Chhindwara District.

Some time later, there was a violent recrudescence of eruptive activity, and new fissures were opened out from time to time through which enormous volumes of lava were extravasated. But now there appears to have been a gradual diminution in the eruptive area, the general tendency being for the concentration of the eruptive fissures in the central part of the original basin, in the country within a radius of about 100–150 miles from Bombay. Side by side with this, as a consequence of the diastrophism which ultimately brought about the foundering of this part of the Gondwanaland southwest of Bombay, there appears to have arisen a gradual and gentle 'sagging' or 'warping' of the ground which became more and more pronounced as we approached the centre of the new area of eruptive activity. Thus there would come about in this region a fairly pronounced depression, gradually shallowing away as we went outwards and finally merging into the flat country of the lower traps all round. The lava flows succeeding the lower traps were more or less confined to this depressed area, the floor of which appears to have further subsided gradually in course of time under the weight of the increasing lava flows above. The diastrophism in this area accompanied by the voluminous extrusion of the underlying basaltic magma must have disturbed the isostatic equilibrium, so that locally the crust began to yield and sag under the increasing load above—a load composed of basaltic lava which is much heavier than normal sediments. Thus arose conditions favourable for the accumulation of enormous thicknesses of lava, reaching a maximum of about 5,000 feet or more in the central part of the area,— the different flows making up this thickness being under these conditions always more or less horizontal. These constitute what we now call the middle traps. This second eruptive activity was much more powerful than the first and very much larger volumes of lava were extravasated. These eruptions were obviously so continuous both in time and space, that no inter-trappean sedimentary beds could be formed. At the close

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[13] L. L. Fermor and C. S. Fox, "The Deccan Trap Flows of Linga, Chhindwara Dt., C.P.," *Rec. Geo. Sur. Ind.,* 1916, 47, Pt. 2, pp. 103–120.

of this second and most important stage in the formation of the Deccan traps, the lava flows (of the first and second periods together) would have covered a very extensive area including part of the Gondwanaland to the southwest attaining their maximum thickness in the central part of the area near Bombay.

Some time after the formation of the middle traps, there was again a recurrence of eruptive activity, but now confined to an area even smaller than that of the second series of eruptions—just within a radius of a few miles round about Bombay. These lava flows, the upper traps of the present day, represent the last stages in the decline of volcanic activity, and were feeble and intermittent. These lavas, like the later flows of the middle trap period, had to come out through fissures cutting through a great thickness of the traps below, and were therefore naturally accompanied by the formation of ash beds. During the long interval of time that had elapsed subsequent to the formation of the middle traps, subaerial denudation had carved out irregularities on their surface giving rise to favourable conditions for the deposition of freshwater sediments here and there. These were covered by the subsequent upper lava flows and became inter-trappean beds. Similar patches of inter-trappean sediments were also formed locally in the interval between successive flows of the uppermost traps. Thus so far as the present Deccan trap area is concerned, it would appear there was a gradual shifting from east to west of the chief centres of eruption during the trap period ; or in the words of Dr. Fox[14] : "I have felt that in a general way the earliest outburst of activity was in northeastern India, and that, broadly speaking, the successive series of eruptions occurred in newer areas each further west than the previous."

Not long after the close of the upper trappean period, there came about the foundering of the land bridge between India and Madagascar and with it went down a part of this great trap formation below the sea. The western coast line of India was now established practically in its present configuration. From that day right up to the present moment, the Deccan trap formation in India has been subjected to a continuous process of subaerial denudation. All the irregularities of ground now seen throughout this area are the effects of this denudation, except in a few cases where they may be due to some comparatively more recent and local earth movements.

In connection with these ideas here suggested regarding the conditions of eruption of these lavas, we might recall some of the conclusions arrived at by Geikie[15] from his study of the ancient volcanoes of Great Britain.

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[14] C. S. Fox, "The age of the Deccan Traps," *Curr. Sci.*, 1935, 3, No. 9, p. 430.
[15] A. Geikie, *Ancient Volcanoes of Great Britain*, 1897, Vol. II, pp. 468 and 470.

"There is one striking connection between the sites of the vents and ancient topographical features to which frequent reference has been made in the foregoing chapters. All through the long volcanic history, as far back as such features can be traced, we see that orifices of discharge for the erupted materials have been opened along low grounds and valleys rather than on ridges and hills. * * * A study of the records of volcanic action in Britain proves beyond dispute that the volcanoes of past time have been active on areas of the earth's surface that were sinking and not rising. * * * Subsidence and not upheaval is ultimately the rule over volcanic areas."

Before proceeding further, we may here consider the relationship between the main mass of the Deccan trap and its outliers, as seen at the present day. These outliers are commonly believed to have once formed part of the main area and thus considered as indicating the original extent of the trap formation. Let us consider the tenability of this idea with reference to the two important outliers, one near Rajahmundry and the other in Western Sind.

### Rajahmundry Area.

The occurrence of this outlier has been known for quite a long time and was described by King[16] so far back as 1880. This outlier is now about 210 miles away from the main mass of the Deccan traps ; and the question has been raised whether this small outlier originally formed part of the main body, and has now become separated due to the denudation and removal of the traps in the intervening country, or whether this area of eruption was distinct and separate from the very beginning. W. T. Blanford while accepting that the traps at Rajahmundry belong to the Deccan series, does not think that it is yet satisfactorily shown that these rocks ever extended across the intervening area, although in his opinion, such a former extension is not improbable. A little consideration will show that such a former continuous extension of the traps, say from Nagpur to Rajahmundry, is altogether unlikely. Nowhere in the intervening area have been seen trap dykes which might be considered as representing the original vents through which the lavas flowed out. In the absence of any such indications of former vents the only other way of explaining a continuity is to imagine that the lavas which were extruded through vents located somewhere in the present peripheral regions of the main Deccan trap country, flowed southeast as far as Rajahmundry, a distance of more than 200 miles. This seems hardly possible. Moreover if all this country were once covered by lava, how is it that a small patch is left only near Rajahmundry while all through the intervening area where the lavas would probably be thicker they have been

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16 W. King, "Coastal region of Godavari Dt.," *Mem. Geo. Sur. Ind.*, 1880, **16**, Art. 3.

completely denuded off?  In view of these considerations it seems only reasonable to believe that the Rajahmundry area was the site of an independent eruptive activity during the Deccan trap period, having nothing to do with the main body of the lava flows in Central Provinces. During the first stage of the eruptions when the lower traps were laid down in the main area, there must have opened out an independent fissure probably in some small basin near Rajahmundry through which also some lavas were extruded.  These eruptions, like those in other places along the margin of the main mass, ceased once for all at the close of the lower trappean period ; and what we now see are just the denuded remnants of these lava flows, which more or less correspond in age with the lowest traps of Central Provinces.

### Western Sind.

In his account of the geology of Western Sind, W. T. Blanford[17] has referred to the occurrence of two thin bands of traps in this area—one interstratified with the sandstones just below the Cardita-beaumonti beds, and the other just above the Cardita-beaumonti beds and below the Ranikot series ; and reasons have been given to show that these bands must be considered as thin representatives of the great Deccan trap formation. Now the question is, which part of the latter do these two thin bands in Sind represent ?—a question the answer to which is intimately connected with another very important problem, the age of the Deccan traps, which we may now proceed to consider.

### The age of the Deccan Traps.

This question has been recently receiving a lot of attention, and the present position in this matter has been briefly reviewed in a paper recently published by the present writer[18] on ''The age of the Deccan Traps near Rajahmundry''.  We have now to discuss the question of the age of the Deccan traps as a whole.  First, let us consider when the eruptions started ; in other words, try to determine the lower age limit of these lava flows. In this connection we must, however, remember that as W. T. Blanford has said[19] ''we have no proof that the basement beds of the trap are everywhere of the same age or what is the same, that volcanic outbursts commenced at the same time over all the area covered by them.''  But still let

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[17] W. T. Blanford, "Geology of Western Sind," *Mem. Geo. Sur. Ind.*, 1880, 17, Art. 1.

[18] L. Rama Rao, S. R. Narayana Rau, and K. Sripada Rau, "The age of the Deccan Traps near Rajahmundry," *Proc. Ind. Acad. Sci.*, 1936, 3, No. 2.

[19] W. T. Blanford, "Traps of Western and Central India," *Mem. Geo. Sur. Ind.*, 1867, 6, Pt. 2, p. 151.

us get together all the available evidence. To begin with, take the Rajahmundry area. Here the lava flows (which are equivalent to the lowest flows in the main trap area) rest on a marine limestone which is uppermost cretaceous in age, and their inter-trappean beds have plant fossils with decided tertiary affinities. Then consider the Nagpur-Chhindwara area. Here the lowest trap flows overlie *unconformably* the Bagh and Lameta beds of middle cretaceous age, and here again the earliest inter-trappean beds have numerous plant fossils indicating a tertiary age.[20] The fossil fishes discovered near Dhamni and Dongargaon in Central Provinces have now been shown to belong to the lower inter-trappean beds of this area[21] and we know on the authority of Sir Arthur Smith Woodward that the age of this fish fauna is about lower eocene.[22] Thus from all these evidences in these two areas, it seems reasonable to conclude that the tertiary era had already dawned when the first lavas of the Deccan were poured out.

It appears to the present writer that the position in Western Sind further supports such a conclusion. It has been customary to think that the two thin bands of trap found here associated with the Cardita-beaumonti beds represent the topmost flows of the main area and hence fix the upper age limit of the entire formation. But it seems equally possible that the two bands in Sind are equivalent to the lower flows of the main area, just as in the case of the traps in the other outlying area near Rajahmundry; and this appears to be the more probable view. The Sind outlier to the northwest is perhaps similar to and bears the same relation to the main Deccan trap formation, as the Rajahmundry outlier to the southeast. As in Rajahmundry, so in Sind, there must have been a small independent centre of eruptive activity during the lower trappean period giving rise to a few lava flows. But unlike in Rajahmundry, what has happened in Sind is that these lavas partly flowed across the arm of the northern sea then existing in this area, where the Cardita-beaumonti and the Ranikot beds were being deposited, and thus came to be interstratified with them. These eruptions, however, ceased very soon, and the marine sedimentation simply continued to give rise to the Ranikot, Khirthar, and other tertiary fossiliferous beds of the area. It is significant to note that the two bands of trap in Sind are intimately associated with the Cardita-beaumonti beds, one occurring just below and the other just

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[20] B. Sahni, "The Deccan Traps: Are they Cretaceous or Tertiary?", *Curr. Sci.,* 1934, 3, No. 4, pp. 134–136.

[21] C. A. Matley, "Stratigraphy, Fossils and Geological relationships of Lameta beds of Jubbulpore," *Rec. Geo. Sur. Ind.,* 1929, 53, Pt. 2, p. 159.

[22] A. Smith Woodward, "On some fish remains from the beds of Dongargaon, C.P.," *Pal. Ind. N.S.,* 1908, 3, No. 3, pp. 1–6.

above, a position almost identical with that in Rajahmundry where also the trap overlies a limestone equivalent to the Cardita-beaumonti beds ; and we know that these beds everywhere represent the topmost subdivision of the cretaceous, almost forming the passage into the lower tertiary. Thus on the assumption that the two thin bands of trap in Western Sind represent only the lower flows of the formation, we again come to the same conclusion, that the eruption of the Deccan traps in India started just after the close of the cretaceous, or what is the same, the beginning of the tertiary era—a period of time when extensive fissure eruptions of basaltic lavas appear to have started in many parts of the world.

Another important area where again we have some marine fossiliferous sediments associated with the traps is in the strip of country between Surat and Broach.   In this area we see eocene beds overlying the traps along their western margin.   From this it has been concluded that here again we have an indication of the upper age limit of the Deccan traps showing that the eruptions had ceased by the time the eocene nummulitics were laid down. To discuss how far this conclusion is acceptable, let us consider the geology of this area in greater detail.   It is true that here we have the eocene beds overlying the traps ; but let us also remember that very frequently in this trap area, we see patches of the underlying cretaceous rocks exposed due to the denudation of the traps above ; and that northeast of Broach, for a distance of about 100 miles, the traps overlie directly the archæan rocks. Thus in this area, we have the archæans, a few patches of the cretaceous infra-trappeans (correlated with the Bagh beds), the traps, and the eocene nummulitics above the traps, all in close proximity.   Now the question is to which part of the entire Deccan trap formation could these traps belong ? Before attempting to answer this question let us follow these traps eastwards and examine their position.   Especially useful in this study are the detailed observations recorded by W. T. Blanford[23] in his paper "On the geology of the Tapti and Lower Narbada Valleys and some adjoining districts."   From this paper we gather the following facts :

(1)   On the western side of this area, near Rajpipla, Surat and Broach, the eocene nummulitics overlie the traps, and there is a pronounced unconformability between the two.

(2)   All along the northern and eastern borders of this trap area we see patches of the underlying cretaceous beds which are stratigraphically equivalent to the Bagh beds.

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[23] W. T. Blanford, "On the geology of the Tapti and Lower Narbada Valleys and some adjoining districts," *Mem. Geo. Sur. Ind.*, 1869, 6, Pt. 3, Art. 6.

(3) Wherever the traps are seen to overlie the infra-trappean creta-
ceous beds, an unconformability is noticed.

(4) In some places as in the neighbourhood of Betul at the eastern
end of the area, the traps (immediately above the cretaceous
beds) have inter-trappean sediments with fossils like *Physa,
Lymnea, Paludina* and *Valvata* similar to those of the inter-traps
in the Nagpur-Chhindwara area.

(5) In some places, as for example in the country between the Machuk
and the Tawa, large outliers of traps are seen to overlie the
metamorphic rocks. "Where denudation has so far removed
the traps that the old surface is once more visible, the hard
ridges again protrude while some trap yet remains in the hollows
between them. Trap dykes occur occasionally in the meta-
morphics."

All these considerations must naturally make us pause and think whether
these traps including those of Surat and Broach could really represent the
latest and therefore the youngest lava flows. If they do, the entire Deccan
trap formation, on these evidences, would be confined to a very small period
of time somewhere between the Cenomanian and the Danian—particularly
so because of the pronounced unconformability noticed everywhere between
the traps and the underlying Bagh beds on the one hand, and between the
traps and the overlying nummulitics on the other. This proposition seems
hardly tenable. What is more likely the case is that the trap rocks referred
to above including those of Surat and Broach, really belong to the base of
the formation, like those of the Nagpur-Chhindwara region. In both areas,
they overlie the Bagh beds unconformably; but whereas in the Nagpur-
Chhindwara area, these lower traps have not been covered by any later sedi-
mentaries, those in the neighbourhood of Surat and Broach are locally over-
laid by the eocene beds, just as in Western Sind where also we have the trap
flows (overlying the Cardita-beaumonti beds) covered by the tertiaries. Of
course, the tertiary sequence in Sind happens to be much more complete
than near Surat and Broach; but this makes no difference. So far as the
traps are concerned, the position in both the areas appears to be essentially
the same. The eocene nummulitics in either case appear to mark only the
close of the lower trappean period. Elsewhere the eruptive activity continued
even with increasing vigour and finally died out only very much later. If
so, what exactly is this upper age limit of the Deccan trap formation?

Here the inter-trappean beds associated with the highest traps near
Bombay should help us if they contained any fossils of stratigraphical value.
But so far no such fossils have been recognised. It may however be pointed

out that from a study of the volcanic rocks themselves of the coastal tracts near Bombay, Salsette and Bassein, Prof. K. K. Mathur[24] comes to the conclusion that there must have been an appreciable gap in time between the middle and the upper divisions of the Deccan trap formation, and says : "It is by no means certain that the Cardita-beaumonti beds of Sind fix the upper time limit for the igneous activity of the Bombay coast. There is at least a possibility that it may be of a much later date." Thus from all these considerations it would appear that the eruptions which began at the close of the cretaceous period not only continued throughout the eocene but extended even into later periods. This would imply that the Gondwanaland southwest of Bombay continued to exist throughout this period ; for its final submergence happened only after the trappean period. Such a late survival of this part of the Gondwanaland is not at all unlikely ; As F. R. Cowper Reed[25] says : "The truncated edge of the table land in South Africa (where the marginal faults involve the tertiary beds) and the similarly abruptly broken edge of the volcanic plateau of the Indian peninsula, prove that some of the downward movements took place much later and in post-cretaceous times." And then again, zoologists demand the existence of a land mass (Lemuria) in the western Indian Ocean as late as the development of the land forms of the present Oriental and African life-provinces in order to explain their distribution.

In any case there seems to be no doubt that the entire Deccan trap formation must have covered a fairly long period of geological time. In addition to some of the internal evidences in support of such a conclusion already enumerated in an earlier part of this paper, we have the evidence afforded by similar fissure eruptions elsewhere. Take for instance the Oregonian region in the United States. Here we have basaltic lava flows covering an area approximately equal to that of the Deccan trap formation but with only about half its maximum thickness ; and yet the Oregonian eruptions are known to have begun in the eocene and reached their maximum in the miocene period. Consider again the case of the tertiary volcanic eruptions of Britain, after a full study of which Geikie[26] writes as follows : "The region within which volcanic activity displayed itself during older tertiary time in the British Isles embraces a total area of more than 40,000 sq. miles. Over that extensive region volcanic phenomena were displayed during an enormously protracted interval of geological time. The earliest beginnings of disturbance may possibly have

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[24] K. K. Mathur and P. R. Jagapathi Naidu, "Volcanic activity of the coastal tracts of Bombay, Salsette and Bassein," *Malaviya Commemoration Volume*, 1932, p. 800.

[25] F. R. C. Reed, *The Geology of the British Empire*, 1921, p. 288.

[26] A. Geikie, *Ancient Volcanoes of Great Britain*, 1897, 2, p. 462.

started in the eocene, and the final manifestations may not have ceased until the miocene period.   So prolonged was the duration of the eruptions that enormous topographical changes from denudation, and probably also considerable variation in the fauna and flora, alike of land and sea, may have been effected."

When we thus see that in other parts of the world, fissure eruptions hardly equal to, and frequently much less than, half the magnitude of the Deccan traps require for their formation a period of time covered by the eocene, oligocene and miocene systems together, how can we believe that in India, the entire duration of the Deccan trap formation is confined to a small period of time just straddling the close of the cretaceous and the beginning of the tertiary era ?

## Summary.

After recapitulating some of the main facts about the Deccan traps which have been definitely established, and drawing attention to the connection between this igneous activity and the disruption of the Gondwana continent, a new interpretation of the geological history of the Deccan trap period has been put forward on lines which it is expected may ultimately lead to a satisfactory solution of the many knotty problems connected with this great volcanic rock-formation.   The relationship between the main mass of the Deccan trap and its two important outliers one near Rajahmundry and the other in Western Sind is next considered.   The problem of the age of the Deccan traps is discussed on the basis of all the evidence available in the different areas, from which it would appear that the eruptions began at the close of the cretaceous, and continued not only throughout the eocene but extended even into later periods.

# GENIC ANALYSIS OF RICE.

## I. Grain Shedding.

BY B. S. KADAM,

*Crop Botanist to the Government of Bombay, Karjat.*

## *Introduction.*

VARIETIES of rice greatly differ in their capacity to shed grains at maturity. The cultivated varieties can be classified as shedding badly and non-shedding. The character of shedding is highly developed in the wild rice so much so that at maturity any slightest disturbance to the plant causes the grains to fall. This phenomenon is utilised by the wild rice in insuring propagation as the shedded grains are disseminated far and wide by the rain waters or by the streams around which the wild rice abounds.

The shedding of grain helps the wild rice to infest fields of cultivated rice. At harvest, wild rice plants shed grains abundantly or wholly resulting in great loss to the cultivators. The encroachment of wild rice is specially manifest in tracts where transplanting of rice is not in vogue. In the southern division of the Bombay Presidency there is a tract known as *Mallad* where wild rice has become a great nuisance to the cultivated rice (Salimath, 1921). It is also a pest in the Central Provinces (Roy, 1921).

The Department of Agriculture in the Presidency has therefore been devoting much attention to the problem of exterminating wild rice. Bhalerao (1930) has studied extensively the botanical and agronomic features of the problem. Although attempts have been made to determine the inheritance of such an important character in the wild rice no definite results have been obtained. The present paper summarises the results on the genetics of shedding of grain.

## *Previous Literature.*

Although grain shedding is an important character it does not seem to have received much attention by rice geneticists, Kato (*cf.* Ikeno, 1927) is the first to report inheritance of grain shedding in rice. He found dominance of non-shedding character in $F_1$ and a ratio of 3 non-shedding to 1 shedding in $F_2$. He seems to have observed such behaviour in many Japanese

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varieties. Jones (1933) confirmed Kato's results by crossing Californian rices with Chinese shedding varieties.

Bhalerao (1930), dealing with wild rices of the *Mallad* tract of the Bombay Presidency, found shedding types yielding both shedding and non-shedding plants. He also observed non-shedding plants giving both the types. He was working with material collected from the fields and with natural crosses. His conclusions are indefinite.

Mitra and Ganguli (1932) mention dominance of the shedding habit of the wild rice in $F_1$. They further observed that most of the plants in $F_2$ were shedding, some intermediate, while none were non-shedding like culti-vated rice, *Latisail*. The same behaviour was observed in $F_3$.

### *Material and Methods.*

The investigation reported in this paper was conducted at the Rice Breeding Station, Karjat, Kolaba, India.

The wild rice used in the present study was collected locally in the year 1926. It was subsequently purified. The plant of the wild rice is procum-bent, highly tillering and possesses anthocyanin pigment in various parts. The husk of the grain is blackish and the kernel red. The grains possess long awns and are completely shed at maturity (see Plate X).

The other variety, *Paungbalaung* 3, was obtained from the Economic Botanist, Burma, in 1930. The variety is an improved type. It is erect in growth, free from any anthocyanin pigment, awnless, and does not shed grain.

The two varieties were chosen to study the inheritance of shattering of grain as they represented the character most highly developed in both directions. Crosses were made in the year 1932. The wild rice was used as the male parent. The $F_1$ generation was raised in 1933. There were three $F_1$ plants and all showed complete shedding of grain. One of the $F_1$ plants was protected under a cloth bag to raise the $F_2$ generation in the succeeding year. Hundred and sixty-two plants were obtained in the $F_2$ generation in 1934 and 48 families were grown in $F_3$ in the following year.

The shattering of grain presented great difficulty in harvesting the crop. Each plant in $F_2$ and $F_3$ was tied up below the panicle with paraffined thick brown paper to hold the grains. The paper was so tied as to form a funnel around the panicles. The shedded grains were held in the hallow of the funnel. It was observed that no grains could pass through, but rain water could freely drain off leaving the seeds dry. The harvesting was done

by shearing off the plants below the paper and collecting the grains in a dish. The earheads and loose grains were then transferred to paper bags.

The shedding of grain was observed in the laboratory. The plants could easily be classified as shedding or non-shedding.

### Results.

Observations under power glass indicate that the stem of the grain in the wild rice is not so deeply attached as in the Burmese variety. The cavity at the lower end of the grain is larger and shallower in the wild rice than in the Burma type. In addition to these differences the shedding of grain must also be occasioned by a special abscission layer between the cavity of the grain and its peduncle as observed by Takenouchi (1924). Takenouchi found 1 to 3 layers of lignified thin-walled cells at the juncture of the rice grain and its supporting stalk.

*$F_1$ generation.*—The $F_1$ plants showed complete shedding of grain indicating that the character of the wild rice is fully dominant.

*$F_2$ generation.*—The $F_2$ generation consisted of 162 plants; of these 15 were non-shedding, like the Burma parent, and 147 showed grain shedding. The segregation approximated a 15 : 1 ratio; the expected numbers being 152 shedding and 10 non-shedding. The deviation of 5 plants gives, for $n = 1$, $X^2 = 2 \cdot 6645$, a value of P between $\cdot 1$ and $\cdot 2$. The $\cdot 05$ point is taken as the level of significance and on this basis the agreement between the observed and expected frequencies of the two types of plants may be considered satisfactory.

The $F_2$ generation indicates that there are two duplicate genes causing shedding of grain in the wild rice. On this assumption both digenic and monogenic ratios were expected in the $F_3$ generation.

*$F_3$ generation.*—Forty-eight families were grown in the $F_3$ generation. Out of these, 21 families were pure for the shedding character (1, 2, 8, 12, 14, 17, 18, 21, 27, 28, 29, 30, 37, 38, 39, 40, 41, 43, 46, 47 and 50). The families 16, 19, and 22 were non-shedding and gave only non-shedding progeny. The remaining 24 families were heterozygous. Of these, 15 families segregated in 15 : 1 ratio while 9 were monogenic. The segregation of each family is shown in Tables I and II.

## TABLE I.

*Families showing* 15 : 1 *Ratio of Shedding and Non-Shedding Plants in the $F_3$ Generation of* ♀ *Paungbalaung* 3 × ♂ *Wild Rice.*

| Culture No. | Observed | | Expected | | Dev. + − | Total No. of plants | $X^2$ | P. between |
|---|---|---|---|---|---|---|---|---|
| | Shedding | Non-shedding | Shedding | Non-shedding | | | | |
| 3 | 50 | 4 | 50·62 | 3·38 | 0·62 | 54 | 0·1213 | ·70 & ·80 |
| 5 | 49 | 2 | 47·81 | 3·19 | 1·19 | 51 | 0·4735 | ·30 & ·50 |
| 6 | 51 | 4 | 51·56 | 3·44 | 0·56 | 55 | 0·0973 | ·70 & ·80 |
| 7 | 50 | 6 | 52·50 | 3·50 | 2·50 | 56 | 1·9047 | ·10 & ·20 |
| 9 | 42 | 2 | 41·25 | 2·75 | 0·75 | 44 | 0·2181 | ·50 & ·70 |
| 10 | 40 | 3 | 40·31 | 2·69 | 0·31 | 43 | 0·0381 | ·80 & ·90 |
| 11 | 40 | 2 | 39·38 | 2·62 | 0·62 | 42 | 0·1565 | ·50 & ·70 |
| 13 | 42 | 3 | 42·19 | 2·81 | 0·19 | 45 | 0·0136 | ·90 & ·95 |
| 20 | 41 | 4 | 42·19 | 2·81 | 1·19 | 45 | 0·5375 | ·30 & ·50 |
| *23 | 21 | 3 | 22·50 | 1·50 | 1·50 | 24 | 1·6000 | ·20 & ·30 |
| 24 | 40 | 5 | 42·19 | 2·81 | 2·19 | 45 | 1·8205 | ·10 & ·20 |
| 25 | 41 | 2 | 40·31 | 2·69 | 0·69 | 43 | 0·1888 | ·50 & ·70 |
| 31 | 41 | 4 | 42·19 | 2·81 | 1·19 | 45 | 0·5375 | ·30 & ·50 |
| *34 | 12 | 1 | 12·19 | 0·81 | 0·19 | 13 | 0·0476 | ·80 & ·90 |
| *42 | 31 | 1 | 30·00 | 2·00 | 1·00 | 32 | 0·5333 | ·30 & ·50 |
| | | | | | | | $\Sigma X^2$ 8·2883 | ·80 & ·90 |
| Total | 591 | 46 | 597·19 | 39·81 | 6·19 | 637 | 1·0267 | ·30 & ·50 |

\* Population low due to poor setting of the $F_2$ plant.

It will be seen that all the 15 cultures show good agreement on the basis of a 15 : 1 ratio. The total $X^2 = 8\cdot2883$, for $n = 14$, is between ·80 and ·90 showing that the agreement between the families is excellent. The total

number of plants of the 15 families resolve in 591 shedding and 46 non-shedding, the deviation being of only 6 plants from the expectation with a probability that the $X^2$ value would exceed by chance between ·30 and ·50.

The behaviour of the 9 families showing monogenic ratio of 3 shedding to 1 non-shedding is summarised in the following table.

TABLE II.

*Families showing* 3 : 1 *Ratio of Shedding and Non-Shedding Plants in the $F_3$ Generation of* ♀ *Pungbalaung* 3 × ♂ *Wild Rice.*

| Culture No. | Observed | | Expected | | Dev. + — | Total No. of plants | $X^2$ | P. between |
|---|---|---|---|---|---|---|---|---|
| | Shedding | Non-shedding | Shedding | Non-shedding | | | | |
| *4 | 23 | 7 | 22·50 | 7·50 | 0·50 | 30 | 0·0444 | ·80 & ·90 |
| 15 | 38 | 6 | 33·00 | 11·00 | 5·00 | 44 | 3·0303 | ·05 & ·10 |
| 26 | 31 | 10 | 30·75 | 10·25 | 0·25 | 41 | 0·0081 | ·90 & ·95 |
| *33 | 7 | 2 | 6·75 | 2·25 | 2·25 | 9 | 0·0370 | ·80 & ·90 |
| *35 | 13 | 3 | 12·00 | 4·00 | 1·00 | 16 | 0·3055 | ·50 & ·70 |
| *36 | 18 | 3 | 15·75 | 5·25 | 2·25 | 21 | 1·2857 | ·20 & ·30 |
| 44 | 34 | 10 | 33·00 | 11·00 | 1·00 | 44 | 0·1212 | ·70 & ·80 |
| 48 | 35 | 9 | 33·00 | 11·00 | 2·00 | 44 | 0·4848 | ·30 & ·50 |
| 49 | 33 | 10 | 32·25 | 10·75 | 0·75 | 43 | 0·0697 | ·70 & ·80 |
| | | | | | | | $\Sigma X^2$ 5·3867 | ·70 & ·80 |
| Total | 232 | 60 | 219·00 | 73·00 | 13·00 | 292 | 3·0868 | ·05 & ·10 |

* Population low due to poor setting of the $F_2$ plant.

It will be noted that all the families show good agreement within and between themselves. The family 15 shows rather a large deviation but the probability of exceeding the $X^2 = 3·0303$ is between ·05 and ·10.

The segregation of the two types of plants in the total of the 9 families deviates by 13 plants from the expected proportion. The value of P is between ·05 and ·10. The total $X^2$, 5·3867, of the 9 families indicates that the agreement between them is excellent.
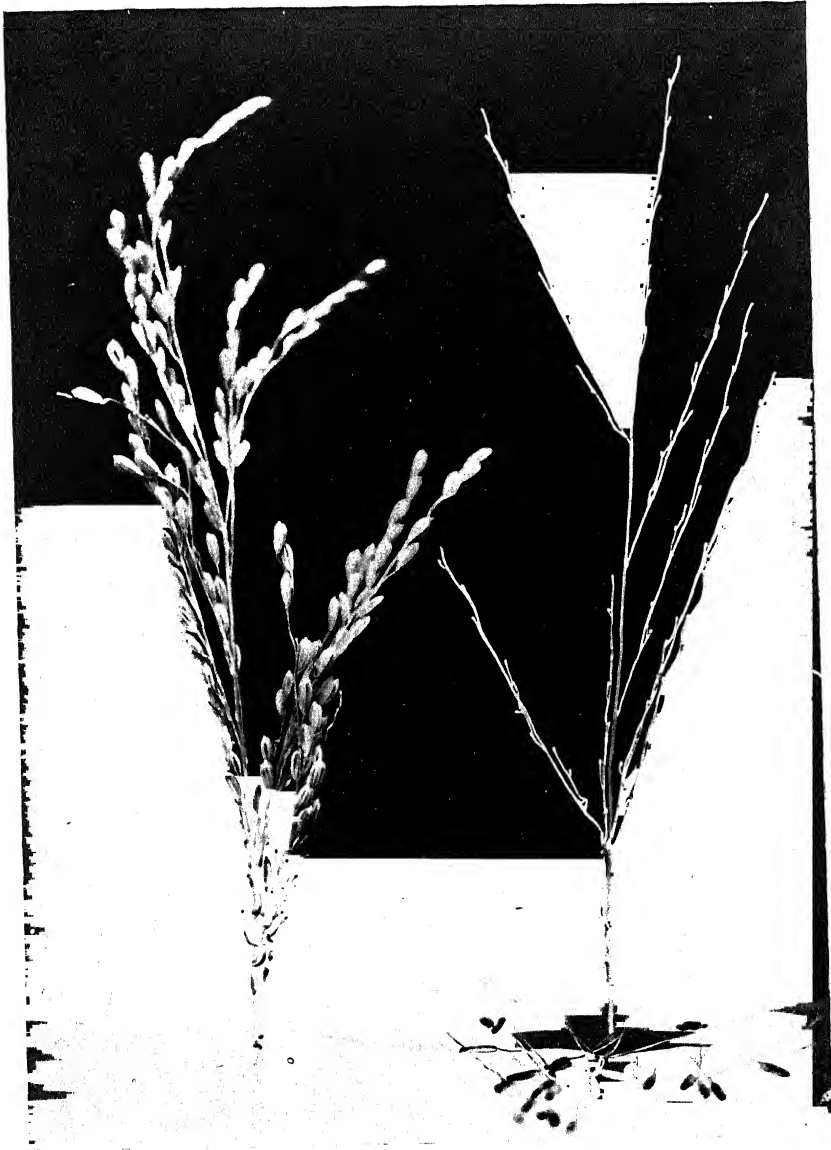
Panicles of the Burma variety and of the wild rice.
Note the complete shedding of grain of the wild rice.

The foregoing experimental evidence supports the contention that duplicate genes are involved in producing shedding of grain. Indeed not only there is digenic and monogenic segregation in $F_3$ but the genotype distribution of the $F_3$ families closely corresponds the expected grouping. The $F_3$ families fall into 21 pure for shedding, 15 segregating in 15 : 1 ratio, 9 segregating in 3 : 1 ratio and 3 pure for non-shedding. The expected figures are 21, 12, 12 and 3 respectively.

The genes are designated $Sh_1$ and $Sh_2$. The genotype of the wild rice and the Burmese variety must be $Sh_1Sh_1\ Sh_2Sh_2$ and $sh_1sh_1\ sh_2sh_2$ respectively.

*Summary.*

The local wild rice, which sheds its grain completely, was crossed with a Burmese variety, *Paungbalaung* 3, which is a non-shedder. The character of the wild rice is completely dominant and is caused by two duplicate genes $Sh_1$ and $Sh_2$.

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* Original not seen; cited by Ikeno and Jones.

*Author's Note.*—While this paper was in Press an article on grain shedding in rice by Ramiah and Rao appeared in the July, 1936, issue of the *Madras Agricultural Journal,* Vol. 24. These investigators found $F_1$ intermediate. The parents had mean shedding of 3·54 and 34·3 grains with a range of 0–10 and 17–56 grains respectively. The $F_2$ had a mean of 12·34 grains, and there was significant positive correlation between $F_2$ and $F_3$ generations. The results indicated that non-shedding was dominant and was due to more than one gene.

# ON TWO COLLECTIONS OF THE OPHIDIAN GENUS, *CYLINDROPHIS* WAGLER.

By Beni Charan Mahendra.

*(From the Department of Zoology, St. John's College, Agra.)*

## 1. Introduction.

Of the six[1] species of *Cylindrophis* Wagler so far described, two are found within the limits of 'British India'[2] as defined by Boulenger (1890) : *C. rufus* (Laurenti.) in Burma, Malay Peninsula, Siam, Indo-China and Malay Archipelago ; and *C. maculatus* (Linné) in Ceylon. Of these two species, I have carefully examined two representative collections comprising 22 specimens altogether, and my observations, which are recorded in the present paper, differ to a great extent from the descriptions and key characters, given for these species by Boulenger and later workers.

I am indebted to the Director of Zoological Survey of India and the Honorary Secretary, Bombay Natural History Society, for the loan of their valuable collections for this study, and to Prof. L. P. Mathur for much encouragement. I am also grateful to Dr. Malcolm A. Smith, not only for going through the original manuscript of this paper and giving me the benefit of his mature herpetological judgment, but also for examining a large number of specimens in the British Museum for me and for preparing a new key to distinguish these species.

## 2. Material.

The following details about the specimens I examined are worth recording :—

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[1] While Boulenger (1890, 1893) gave descriptions of only three species, de Rooij (1917) described five. The sixth was added by Malcolm Smith from Celebes in 1927.

[2] To quote Boulenger himself, "The area here accepted as that of the *Fauna of British India* has been defined in the Introduction to the Mammalia of the present series, and may be briefly described as British India with Burma and all other dependencies, and with the addition of Ceylon—Baluchistan, Kashmir, Ladák, and all Cis-Himalayan States being included, Afghanistan, Tibet proper, China, Siam and the Malay Peninsula south of Tenasserim excluded". (Preface, pp. iv–v of *Fauna of British India. Reptilia and Batrachia,* 1890.)

*Specimens belonging to the Bombay Nat. Hist. Soc. :*

C. *rufus*—

| | | | | |
|---|---|---|---|---|
| 428 | Burma .. | collected by | Col. C. J. Bigham .. | (31–12–07) |
| 429 | ,, | ,, | Maj. F. Wall | (31–12–07) |
| 104 | ,, | ,, | ,, | (24– 6–08) |
| 20–1 | ,, | ,, | ,, | |
| 20–5 | Taugyi Shan States, Burma .. | ,, | S. Lightfoot | (Dec. 1912) |
| 20–6 | ,, | ,, | ,, | ( ,, ) |
| 20–7 | Pyawbroe Burma, | 700 ft. | Capt. F. E. Venning | ( 30– 7–13 ) |
| 20–8 | Lasheo U. S. States, Burma .. | | A. J. Butterwick .. | (May 1916) |
| 20–9 | Sinlum Kaba U. Burma .. | 6,000 ft. | P. M. R. Leonard | |
| 20–10 | Katha Burma | | Lt. W. L. Brooks. | |
| 20–11 | ,, | | ,, | |
| 20–12 | Mandalay Burma . | | G. C. Stuart. | |

C. *maculatus*—

| | | | | |
|---|---|---|---|---|
| 430 | Ceylon | | | (31–12–07) |
| 107 | ,, | | Major F. Wall | (24– 6–08) |
| 105 | ,, | | ,, | ( ,, ) |

*Specimens belonging to the Indian Museum :*

| | | | |
|---|---|---|---|
| 4203 | C. *rufus* .. | .. | Ava, Burma. |
| 4204 | ,, .. | .. | Prome, Burma. |
| 7018 | ,, .. | .. | Amherst, Tenasserim. |
| 13305 | ,, .. | .. | Singapore. |
| 4658 | ,, .. | .. | Johore. |
| 6994 | C. *maculatus* | .. | Ceylon. |
| 7016 | ,, .. | .. | West Province, Ceylon. |

### 3.   *Distinction between the Species (Boulenger).*

According to the account given by Boulenger (1890; 1893), there are three[3] species of *Cylindrophis* Wagler, which differ from each other in the following features :

(1) *Ratio of the diameter of the eye to its distance from the nostril :*—In C. *rufus*, this ratio is about 1 : 2 or 2 : 5 (*i.e.,* expressed in decimals for the sake of comparison, ·5 or ·4). In C. *maculatus*, it is 1 : 3 to 1 : 4 (*i.e.,* ·3 to ·25). In C. *lineatus*, it is about 1 : 4 (*i.e.,* ·25).

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[3] See footnote 1.

(2) *Inter-ocular width as compared to the length of the snout* :—Greater in *C. rufus* ; equal in both the others.

(3) *Frontal* is at least equal to *supraocular* in length in *C. rufus*, usually a little less than supraocular in *C. maculatus*, and about equal to Supraocular in *C. lineatus*.

(4) *Frontal as compared to the length of Parietal* :—Greater in *C. rufus* ; usually a little less in *C. maculatus* ; a little greater in *C. lineatus*.

(5) *Frontal as compared to distance from Rostral* :—at least equal in *C. rufus*.

(6) *No. of costals* :—19 or 21 in both *C. rufus* and *C. maculatus* ; 21 in *C. lineatus*.

(7) *No. of ventrals* :—185 to 245 in *C. rufus* ; 189 to 201 in *C. maculatus* ; 215 in *C. lineatus*.

(8) Ventrals not twice the contiguous series in size in *C. rufus* and *maculatus*. Nearly twice in *C. lineatus*.

(9) *No. of subcaudals* :—5–10 in *C. rufus* ; 4–6 in *C. maculatus* ; 9 in *C. lineatus*.

(10) *Colouration* :—Alternating light cross-bands present or absent in *C. rufus* ; belly with transverse bands or spots. In *C. maculatus*, black network enclosing two series of large reddish-brown spots along the back ; lower parts white, variegated with black. In *C. lineatus*, blackish brown above, with two white stripes ; belly white, with alternating black cross-bands ; head and tail yellowish.

(11) *Distribution* :—*C. rufus*—Burma Hills ; *C. maculatus*—Ceylon plains ; *C. lineatus*—Singapore.

### 4. *Comparison of the Diameter of the Eye to its Distance from the Nostril.*

The observations that I have made about this ratio are given in the accompanying table. The right and the left sides of the same individual sometimes differ a great deal from each other in this respect. As a matter of fact, the eye is more or less oval, and therefore the diameter depends on the direction of the measurement. I have taken the greatest diameter into consideration. It is possible that the diameter of the eye might have been affected in some cases by the specimens remaining preserved in fluid for a very long time ; but, on the whole, we can assume that the distance from the nostril has also been similarly affected. In any case, I believe that the figures obtained are quite representative in the majority of specimens observed.

TABLE.

*Ratio of the Diameter of the Eye to its Distance from the Nostril (Cylindrophis Wagler.)*

| No. of Specimen | Owned by | The name of the species | Left Side | | | Right Side | | |
|---|---|---|---|---|---|---|---|---|
| | | | Diameter of Eye (mm.) | Dist. from Nostril (mm.) | Ratio (also in decimals, for comparison) | Diameter of Eye (mm.) | Dist. from Nostril (mm.) | Ratio (also in decimals for comparison) |
| 430 | B. N. H. S. | C. maculatus | ·63 | 1·62 | $\frac{63}{162}$ (·39) | ·69 | 1·58 | $\frac{69}{158}$ (·44) |
| 107 | ,, | ,, | ·79 | 1·88 | $\frac{79}{188}$ (·42) | ·79 | 1·85 | $\frac{79}{185}$ (·43) |
| 105 | ,, | ,, | 1·06 | 2·41 | $\frac{106}{241}$ (·44) | 1·09 | 2·34 | $\frac{109}{234}$ (·47) |
| 6994 | Ind. Mus. | ,, | ·89 | 2·18 | $\frac{89}{218}$ (·41) | ·92 | 2·21 | $\frac{92}{221}$ (·42) |
| 7016 | ,, | C. rufus | ·89 | 2·41 | $\frac{89}{241}$ (·37) | ·99 | 2·21 | $\frac{99}{221}$ (·45) |
| 428 | B. N. H. S. | ,, | ·69 | 1·82 | $\frac{69}{182}$ (·38) | ·69 | 1·88 | $\frac{69}{188}$ (·37) |
| 429 | ,, | ,, | ·83 | 2·31 | $\frac{83}{231}$ (·36) | ·86 | 2·34 | $\frac{86}{234}$ (·37) |
| 104 | ,, | ,, | ·83 | 1·75 | $\frac{83}{175}$ (·47) | ·86 | 1·78 | $\frac{86}{178}$ (·48) |
| 20 (1) | ,, | ,, | 1·02 | 2·38 | $\frac{102}{238}$ (·43) | 1·06 | 2·38 | $\frac{106}{238}$ (·45) |
| 20 (5) | ,, | ,, | ·76 | 1·52 | $\frac{1}{2}$ (·5) | ·83 | 1·58 | $\frac{83}{158}$ (·53) |
| 20 (6) | ,, | ,, | ·73 | 1·98 | $\frac{73}{198}$ (·37) | : | : | : |
| 20 (7) | ,, | ,, | ·66 | 1·68 | $\frac{11}{28}$ (·39) | ·66 | 1·68 | $\frac{11}{28}$ (·39) |
| 20 (8) | ,, | ,, | ·69 | 1·49 | $\frac{69}{149}$ (·46) | ·73 | 1·49 | $\frac{73}{149}$ (·49) |
| 20 (9) | ,, | ,, | ·73 | 1·91 | $\frac{73}{191}$ (·38) | ·73 | 1·98 | $\frac{73}{198}$ (·37) |
| 20 (11) | ,, | ,, | ·83 | 1·68 | $\frac{83}{168}$ (·49) | ·92 | 1·68 | $\frac{42}{82}$ (·55) |
| 20 (12) | ,, | ,, | ·96 | 2·05 | $\frac{96}{205}$ (·47) | ·92 | 2·08 | $\frac{23}{52}$ (·44) |
| 4203 | Ind. Mus. | ,, | ·63 | 1·42 | $\frac{63}{142}$ (·44) | ·63 | 1·39 | $\frac{63}{139}$ (·45) |
| 4204 | ,, | ,, | ·56 | 1·39 | $\frac{56}{139}$ (·40) | ·59 | 1·39 | $\frac{59}{139}$ (·42) |
| 7018 | ,, | ,, | ·92 | 2·84 | $\frac{92}{284}$ (·32) | ·92 | 2·81 | $\frac{92}{281}$ (·33) |
| 13305 | ,, | ,, | 1·45 | 4·65 | $\frac{145}{465}$ (·31) | 1·06 | 3·47 | $\frac{106}{347}$ (·31) |
| 4658 | ,, | ,, | ·99 | 2·67 | $\frac{99}{267}$ (·37) | 1·12 | 2·64 | $\frac{14}{38}$ (·42) |

I tried several methods for measuring both the diameter of the eye and its distance from the nostril accurately. I began my observations with a pair of dividers, but finding this device to be unreliable at times, especially when the specimen is small, I discarded it in favour of the travelling microscope, which proved to be too cumbersome. One can hardly believe that the individual variations in this respect play only within the limits of a few microns, and I felt that the use of this apparatus was more fastidious than serviceable.

The method that I found most accurate and reliable for my purpose is that of the micrometer device. The snake's head is placed on the stage of a microscope and illuminated with electric light, and the readings are taken with the help of the eyepiece micrometer. Of course, the lowest powers of the microscope were used for this purpose. The method is very good for small specimens.

Specimen 20 (8) of Bombay Natural History Society Museum was much shrunken, and the eye of Specimen 20 (10) was not quite clear. The other specimens do not present any difficulty so far as these readings are concerned, and I hope I am quite accurate to two places of the decimal.

By referring to the table, it becomes clear that the ratio in C. maculatus does not tally precisely with the ratio given by Boulenger ( ·3 to ·25), but is either very near—or is actually—the C. rufus ratio (i.e., ·4). The specimens undoubtedly belong to the species C. maculatus, because of their peculiar colouration and habitat; but these readings do away with this supposed difference between C. maculatus and C. rufus.

Some of the specimens of C. rufus show a ratio lower than ·4; others show a ratio more than ·5.

I was not able to procure any specimens of C. lineatus, but so far as this feature is concerned, it does not make any difference. It is recorded that the diameter of the eye in C. lineatus is about one-fourth of its distance from the nostril; and this ratio is the same as that in C. maculatus. In other words, it is not possible to separate C. lineatus from C. maculatus on this score.

This shows that there is no line of demarcation between these ratios in the three species of Cylindrophis, here considered, and that, therefore, the ratio of the diameter of the eye to its distance from the nostril cannot be regarded as a criterion for distinguishing these forms. Perhaps, the smaller number of specimens observed by previous workers, together with less accurate methods of comparison, led to this faulty distinction.

### 5. Inter-Ocular Width and the Length of Snout.

The inter-ocular width in all the specimens observed by me is not equal to, but greater than, the length of the snout, and thus the distinction between C. rufus and C. maculatus is not tenable in this respect.

It may, perhaps, be useful to mention exactly what I understand by the terms "inter-ocular width" and "length of snout". Fig. 1 is a diagram of the dorsal view of *Cylindrophis* Wagler, and the line *ee'* in it is the inter-ocular width. The snout extends from the anterior end of the eyes to the anteriormost tip of the head (*ll'* in the fig.). I measured these lengths by means of a fine pair of dividers. But in order to be more accurate about the length of the snout than would have been otherwise possible, I erected a level piece of glass quite vertically on my working table and laid the specimen so that the tip of its snout touched the glass and the body was straight. The measurement of the line *oo'* gave the length of the snout.
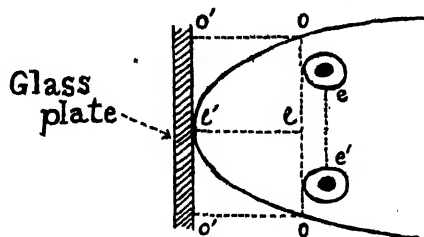


FIG. 1.

### 6. *Length of Frontal Compared to that of Supraocular and Parietal, and to its Distance from Rostral.*

In all the specimens of *C. maculatus* observed by me, the frontal is equal in length to the supraocular. In Specimen No. 430, however, it is slightly less ; but the specimen is injured on the head to some extent. In all the specimens of *C. rufus*, except two, it is greater than the supraocular. In Specimens 20 (10) and 20 (11), it is almost equal to the Supraocular.

Two specimens of *C. maculatus* have got the frontal equal to the parietal. In Specimen 105, the frontal is equal to the parietal on the right side, but is slightly less than the parietal on the left. In Specimen 6994, the frontal is slightly less than the parietal. In all specimens of *C. rufus*, the frontal is greater than the parietal.

*Comparison of Frontal to its Distance from the Rostral.*—Less in Specimen 430 of *C. maculatus*, in all other specimens of this species, equal.

In all specimens, except three, of *C. rufus*, the frontal is greater than this distance. In Specimens 20 (1), 20 (11) and 4203, however, it is equal to this distance.

On the whole, I do not feel that much importance can be attached to the comparison of the length of frontal to other scales ; there does not seem enough discontinuity here to mark off one species from the other. It is extremely likely that the larger the number of specimens examined, the more these relations will be found to grade insensibly from one species to the other.

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### 7. Ventrals, Costals and Subcaudals.

These numbers can be regarded of no consequence in *specific* distinctions, since they overlap in all the three species.

### 8. Colouration.

Colour pattern is the only feature, apart from distribution (*vide infra*), which seems to separate these species. This alone may not, however, be regarded as enough ground for instituting separate species of the genus *Cylindrophis*.
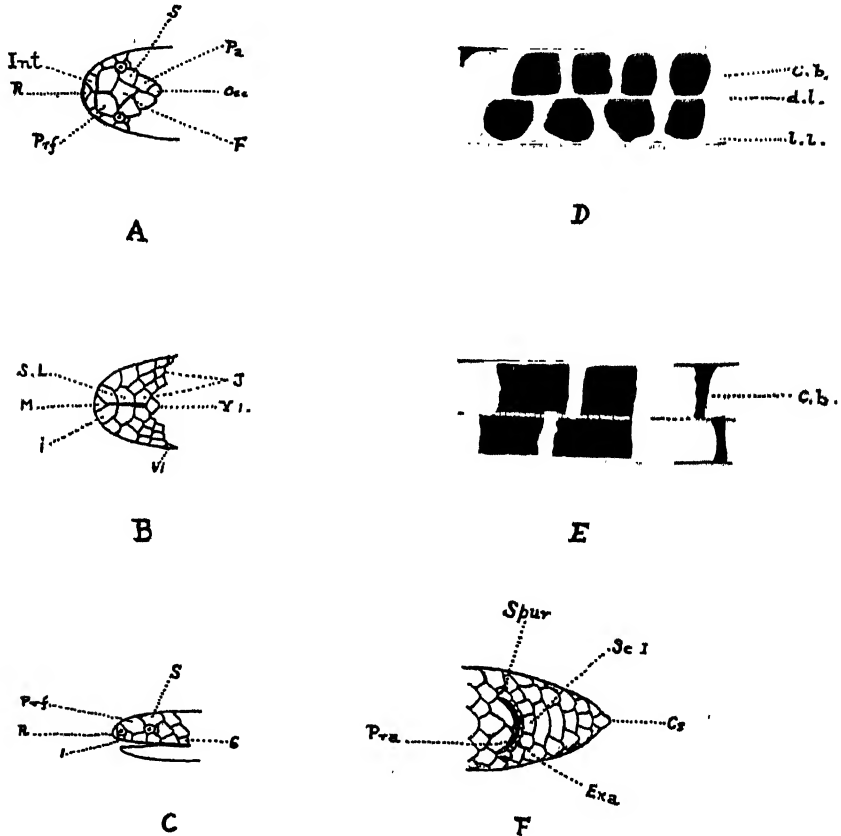


FIG. 2.

A.—Dorsal view of the head shields of *C. maculatus* Linné.
B.—Scales of the lower jaw of *C. maculatus* Linné.
C.—Side view of the head shields of *C. maculatus* Linné.
D.—Colour pattern on the body of *C. maculatus* Linné, as seen from the dorsal side.
E.—Colour pattern on the body of *C. rufus* Laurenti. (Dorsal View.)
F.—Diagram of the scales of the anal region of *C. maculatus* Linné.

It is interesting to note that the colour pattern found in *C. rufus* Laurenti is really a modification of the one found in *C. maculatus* Linné. The black network enclosing two series of spots along the back (*C. maculatus*) is formed by means of three longitudinal stripes visible from above and a number of alternating cross-bands (Fig. 2, D). If we assume that the longitudinal stripes somehow disappeared from the pattern, we come to the condition found actually in *C. rufus* (Fig. 2, E). Here we have a number of half cross-bands on the body alternating with each other and not continuous with each other mesially. Unfortunately I have not had access to any specimen of *C. lineatus* Blanford to compare its colouration with those of *C. rufus* and *C. maculatus*, but the description of its pattern as given by Boulenger makes it appear very likely that it also would prove a variant of the same basic design.

### 9. Distribution.

According to Boulenger (1890), the following is the distribution of these three species :

| | |
|---|---|
| *C. rufus* Laurenti : | Burma and Cochin China to the Malay Peninsula and Archipelago. |
| *C. maculatus* Linné : | Ceylon. |
| *C. lineatus* Blanford : | Only known from Singapore. |

### 10. Discussion.

As is clear from the foregoing observations, the species of *Cylindrophis* Wagler, examined by me, do not differ from each other in the generally accepted distinctive features given by Boulenger (1890) and others, but they differ in their colour scheme and distribution. My first idea on making these observations (Mahendra, 1933) was, that the species were not really valid, and that they represented merely geographical subspecies or varieties, differing in colouration from each other. I have, however, felt it necessary to consult Dr. Malcolm A. Smith and I find that he does not agree with such a conclusion. In a letter addressed to me, dated May 19, 1936, he says : "It is true that the key characters as given by Boulenger break down when a large amount of material is examined, but by abandoning those characters and applying a different set the main points which he sets forth still hold good. I have tested the new key, which I enclose, against a large number of specimens in the Museum and so far it has not failed. The variations in the proportions of the shields are not great, but they appear to be sound specific characters for that genus. Combined with the very distinctive colour pattern, they are, I think, sufficient to maintain the species distinct."

The new key proposed by Dr. Smith runs as follows :—

I.     Breadth of frontal equal to half the distance between
the supraoculars. Rostral as high as broad.

      (a)   Prefrontals broader than long      ..      .. C. *rufus.*

      (b)   Prefrontals longer than broad      ..      .. C. *lineatus.*

II.    Breadth of frontal not half the distance between the
supraoculars. Rostral broader than high.

      Prefrontals longer than broad      ..      .. C. *maculatus.*

*11. Summary.*

The present study shows that the distinctive features, generally recognised between the three species of *Cylindrophis* Wagler, under consideration, do not stand the test of a thorough and intensive scrutiny of a representative collection. The species appear to be valid, but our ideas about their differences have to be modified. A new key for this genus, proposed by Dr. Malcolm A. Smith, is given and it is hoped that the key will stand the test of further scrutiny.

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## LIST OF ABBREVIATIONS USED IN THE FIGURES.

| | | | | | |
|---|---|---|---|---|---|
| *c.b.* | .. | Cross bands. | *Pa.* | .. | Parietal. |
| *Cs.* | .. | Caudal scute. | *Pra.* | .. | Preanal. |
| *d.l.* | .. | Dorsal longitudinal stripe. | *Prf.* | .. | Prefrontal. |
| *Exa.* | .. | Exanal. | *R.* | .. | Rostral. |
| *F.* | .. | Frontal. | *S.* | .. | Supraocular. |
| *Int.* | .. | Internasal. | *Sc.1* | .. | Subcaudal. |
| *J.* | .. | Jugulars. | *S.L.* | .. | Sublinguals. |
| *l.l.* | .. | Lateral longitudinal stripe. | *V.1* | .. | First ventral. |
| *M.* | .. | Mental. | *i–vi* | .. | Infralabials. |
| *Occ.* | .. | Occipital. | *1–6* | .. | Supralabials. |

# THREE NEW SPECIES OF *ZYGNEMA* FROM NORTHERN INDIA.

BY M. S. RANDHAWA, M.SC., I.C.S.

(*Saharanpur.*)

THE writer came across three remarkable species of genus *Zygnema*, during his investigations of the Zygnemales of Northern India. The reproductive phase of these algæ shows many peculiarities. Following is a detailed description of these three new species of *Zygnema*.

## *I.* Zygnema Czurdæ *Sp. Nov.*

Vegetative cells are 20–27 $\mu$ broad, and $1\frac{1}{2}$ to 4 times as long. Two more or less rounded chloroplasts with a conspicuous pyrenoid in each, are seen in each cell. When stained with iodine, some of the chloroplasts show the typical zygnemaceous stellate structure (Fig. 1).

*Reproduction.*—The reproductive phase of this new member of Zygnemales is most remarkable. Both lateral and scalariform conjugation have been noticed in this alga.

(i) *Lateral conjugation.*—Lateral conjugation is the commonest mode of reproduction in this alga. The neighbouring cells give out tent-like protuberances (Fig. 2). In most filaments, it is seen, that such protuberances are given out on one side of the filament only (Fig. 2), while in others these are given out on both sides in an alternate fashion (Fig. 3). The protoplasm with the chloroplasts shows a dislocation from its horizontal position, and it has been noticed, that in some cases, it accumulates in the region of the protuberances (Fig. 3). Ultimately the cell-wall separating the two gametes ruptures, the protoplasm and nuclei coalesce, but the chloroplasts with their pyrenoids remain distinct even in the zygospore.

Both the gametes are morphologically as well as physiologically isogamous. In one filament, I noticed that the upper part, which contains a kidney-shaped zygospore, is cut off from the remaining part of the conjugating cells by means of distinct walls, as in *Zygnema Heydrichii* (Fig. 4). However in most of the filaments the zygospore is seen filling the whole of the conjugation canal area, as well as the lower part of the conjugating cells (Fig. 5).

Probably the zygospore enlarges, presses down the lower arched part of the cell-wall, while the lateral parts are torn away partly by the pressure of the zygospore, and partly by the forces exerted by the movement of the filaments in water.

The zygospores are 30–40 $\mu$ in diameter, and are oval in shape in early stages (Fig. 5), but later on become rounded. Four chloroplasts with a conspicuous pyrenoid in each, and nucleus in the central part may be observed nearly in all the zygospores (Fig. 5). The zygospore wall is composed of three thin layers, all of which are light blue in colour. The exospore and mesospore are smooth, while the endospore is slightly sinuous. When fully mature the zygospores are perfectly round in shape, and the peripheral area surrounding the chloroplasts is full of granular matter (Fig. 6). The middle-basal part of the conjugating cells becomes flattened and the upper part becomes rounded like a dome (Figs. 5, 6). In some filaments, which become more mature, distinct geniculation may be seen, the flattened basal part ruptures, and the zygospore is liberated into water (Fig. 6). The zygo-spores thus produced by lateral conjugation look very much like azygospores produced asexually in forms like *Zygnema reticulatum* Hallas and *Z. fertile* Fritsch. If the early stages showing cells with conjugation processes were not seen, and also the four chloroplasts in some zygospores, these might have been easily mistaken for azygospores.

(ii) *Scalariform conjugation.*—Some of the filaments also show the normal type of scalariform conjugation, with zygospores in the conjugation canal. The conjugation canal becomes distended due to the globose shape of the zygospores (Fig. 7). Even in this scalariform type of conjugation geniculation is noticeable (Fig. 7). Sometimes three or more filaments may be seen conjugating together (Fig. 7).

*Affinities.*—The species of genus *Zygnema*, which come nearest to the present form, are *Zygnema Heydrichii* Schmidle, and *Z. Carteri* Czurda. However it differs from both these in that the zygospore is not confined to the conjugation canal, but encroaches upon the whole of the middle part of the conjugating cells, when it reproduces by lateral conjugation. From *Z. Carteri* it differs in the size of vegetative cells and zygospores. Another related form is *Z. gedeanum* Czurda, which differs from the present form, in that the zygospores produced by lateral conjugation are confined to the upper part of the conjugation canal area only though they are not cut off by any cell-wall from the remaining part of the conjugating cells.

I have named this species after Dr. V. Czurda of Prag who has done such a memorable work in advancing our knowledge of Zygnemales.

*Habit.*—This alga was found free floating in a bluish green mass, along with a species of *Spirogyra* during the third week of February, 1931, in a fresh-water spring at Tahli Sahib, Tehsil Dasuya, District Hoshiarpore, Punjab.

## *II.* Zygnema Iyengari *Sp. Nov.*

Vegetative cells are 18–20 $\mu$ broad and five to eight times as long. Each cell has two rounded chloroplasts (Fig. 8).

*Reproduction.*—Sexual reproduction is not known so far, and the alga reproduces itself by means of squarish or cushion-shaped azygospores. The azygospores are of various shapes (Figs. 9 and 10) and have a constriction in the middle part when fully mature. The cells assume a spindle-shaped appearance due to the peculiar structure of the azygospores, and are shining white in appearance, possibly due to mucilage secretion, though no lamellation is noticeable.

The azygospores are 26–30 $\mu$ long and just as broad in some cases (Fig. 9). Three layers are clearly noticeable in the wall of the azygospores, a bluish exosporium, a dark brown, crinkled and sinuous mesosporium, and a hyaline endosporium.

I have named this alga after Dr. M. O. P. Iyengar of Madras, one of the pioneers in algal research in this country.

*Affinities.*—This alga takes its place in the small Group IV Reticulata of genus *Zygnema*, as classified by Czurda in Heft 9 of *Die Susswasserflora Mitteleuropas*, due to the absence of sexual reproduction. There are three species in this group, *viz.*, *Zygnema reticulatum* Hallas *Z. fertile* Fritsch and Rich, and *Z. Cylindricum* Transeau. From all these this alga differs in the shape and size and structure of the azygospores.

*Habit.*—This alga was found free-floating in the form of a bluish mass of filaments at Shahniwala Tank at Dasuya, District Hoshiarpore, Panjab, during the second week of April, 1931.

## *III.* Zygnema giganteum *Sp. Nov.*

Vegetative cells are 38–48 $\mu$ broad and $1\frac{1}{2}$ to $2\frac{1}{2}$ times as long. In thinner filaments, the chloroplasts show a typically stellate structure each with a conspicuous pyrenoid (Fig. 11). In bigger filaments the chloroplasts are loaded with starch granules, and the stellate structure of the chloroplasts is obscured, and they appear to be more or less rounded in appearance. Cell-wall is fairly thick as compared with other species of *Zygnema*. In most filaments protoplasm with chloroplasts and nucleus is restricted to the middle

part, the peripheral part being full of shining mucilage, secreted by the retreating protoplasm which forms a homogeneous mass (Fig. 11).

*Reproduction.*—Both sexual and asexual modes of reproduction have been noticed in this alga.

(i) *Asexual reproduction.*—Asexual reproduction takes place by means of brick-shaped parthenospores. In early stages, the filaments develop very thick cell-walls, and their chloroplasts become enormously expanded filling nearly the whole of the cell interior. When stained with iodine the chloroplasts become purple, due to the heavy load of starch granules, which envelopes them, and the surrounding parts take up a yellow stain (Fig. 12). The parthenospores develop orange-coloured thick walls, which sometimes show two pyrenoids in the middle part (Fig. 13). The parthenospores are 36–45 $\mu$ broad and 54–96 $\mu$ in length, and may be rectangular or squarish in shape even in the same filament. The parthenospores may be seen singly, or in rows of two or threes, and in later stages whole filaments are converted into chains of parthenospores (Fig. 14).

(ii) *Sexual reproduction.*—The sexual mode of reproduction shown by this alga is also of a very interesting type. Material collected from the same habitat shows that in some filaments zygospores are found in the conjugation canals, and in others in the conjugating cells ; the conjugation being isogamous and anisogamous in the same alga. The only parallel instance of this type of conjugation has been seen in the case of *Zygnema peliosporum* Witt. by Fritsch, but even in that case the two different types of conjugation were seen in material collected in different years from the same habitat. In the present case both types of reproduction were seen in the same material and also transitional stages.

(a) *Anisogamous conjugation.*—This type of reproduction is quite common in most filaments. The conjugation canals do not form a continuous tube but present a ruptured appearance in the middle, surrounded by a granular matter (Fig. 15). The male filaments sometimes show an alternation of cells which produce male gametes, and vegetative cells, in which the chloroplasts are surrounded by a shining mucilaginous material and thick walls (Fig. 15). In later stages these sterile cells become loaded with starch granules, and these also produce abortive conjugation canals (Fig. 16). This shows that these cells also are potentially male, though their activity is very much retarded by the development of thick walls. In other cases no cells are left out as purely vegetative in the male filaments, all of them functioning as males (Fig. 19).

The zygospores are 42–46 $\mu$ and 50–58 $\mu$ long, and are oval in shape. The zygospore wall is composed of two layers only, a thick hyaline and smooth exospore, and a thin, light blue, and smooth endospore. Mesospore is obviously missing. The ripe zygospores are orange-coloured in appearance like the parthenospores.

(b) *Isogamous conjugation.*—This is the commoner mode of reproduction, in this alga. Zygospores are typically egg-shaped in appearance, and project partly into the gametangia, completely filling the conjugation canals at the same time. Zygospores produced by isogamous conjugation are longer than those produced by anisogamous conjugation, being 70–75 $\mu$ long. This is probably due to the fact that in this position more space is available for the lengthwise development of the zygospores (Fig. 18).

In some instances I noticed that male and female gametes instead of meeting and fusing to form zygospores, develop independently into azygospores (Fig. 18).

Sexual differentiation in this species is very much unsettled ; isogamy and anisogamy being found side by side. In one filament isogamy, anisogamy and many intermediate stages between these both were seen (Fig. 17). While majority of the zygospores were clearly produced by anisogamous conjugation, as is apparent from their being entirely confined to the female gametangium, there are some zygospores which are partly formed in the conjugation canal and partly in the female gametangium (Fig. 19). In some only a small part of the zygospore is found projecting into the conjugation canal. The pear-shaped appearance of some zygospores with their pointed ends towards the conjugation canals is explained by the fact that anisogamy has not reached its final stage and in these and both the male as well as the female gametes show a certain amount of activity.

This species combines all the four forms of reproduction known in different species of genus *Zygnema*.

(i) Asexual reproduction by the development of parthenospores.

(ii) Sexual reproduction.

(a) By means of development of zygospores produced isogamously.

(b) By means of zygospores produced anisogamously.

(c) By means of azygospores developed from isogamous gametes.

*Affinities.*—There are two conspicuous peculiarities of this alga. Firstly its modes of reproduction, and secondly its gigantic size.

As regards the combination of isogamous and anisogamous modes of conjugation, it resembles *Zygnema peliosporum* Witt. as recorded by Fritsch

from South Africa.    But it differs from that species in the shape and size of zygospores and vegetative filaments, as well as in the presence of parthenospores.

As regards its size *Z. inconspicuum* Czurfla with its filaments as broad as 39 $\mu$ approaches it, but differences in the shape of zygospores, occurrence of anisogamy with isogamy and presence of parthenospores keep these two forms wide apart.   I have named this form as *Zygnema giganteum*, due to its comparatively big size.

*Habit.*—This alga was found free-floating along with *Zygnema cœruleum* in Siah Baeen, a perennial freshwater stream in Kapurthala State, Punjab, during the second week of March 1931.

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### EXPLANATION OF FIGURES.

#### PLATE XI.

*Zygnema Czurdæ* sp. nov.

FIG.  1.—A vegetative filament showing chloroplasts.  $\times$ 660.

FIG.  2.—A filament showing cells with conjugation processes.  $\times$ 660.

FIG.  3.—A filament showing cells giving out conjugation processes on both sides.  $\times$ 660.

FIG.  4.—A filament showing a bean-shaped zygospore cut off by walls from the remaining part of the cells.  $\times$ 660.

FIG.  5.—A filament showing zygospores filling the entire cells.  $\times$ 660.

FIG.  6.—A filament showing distinct geniculation and ripe zygospores.  $\times$ 660.

FIG.  7.—Three filaments conjugating in a scalariform way.  $\times$ 660.

*Zygnema Iyengari* sp. nov.

FIG.  8.—A filament showing chloroplasts.  $\times$ 660.

FIG.  9.—A filament showing squarish azygospores.  $\times$ 660.

FIG. 10.—A filament showing zygospores with a constriction in the middle.  $\times$ 660.

#### PLATE XII.

*Zygnema giganteum* sp. nov.

FIG. 11.—A filament showing chloroplasts.  $\times$ 660.

FIG. 12.—A filament showing enlargement of chloroplasts and secretion of mucilage prior to formation of parthenospores.  $\times$ 660.

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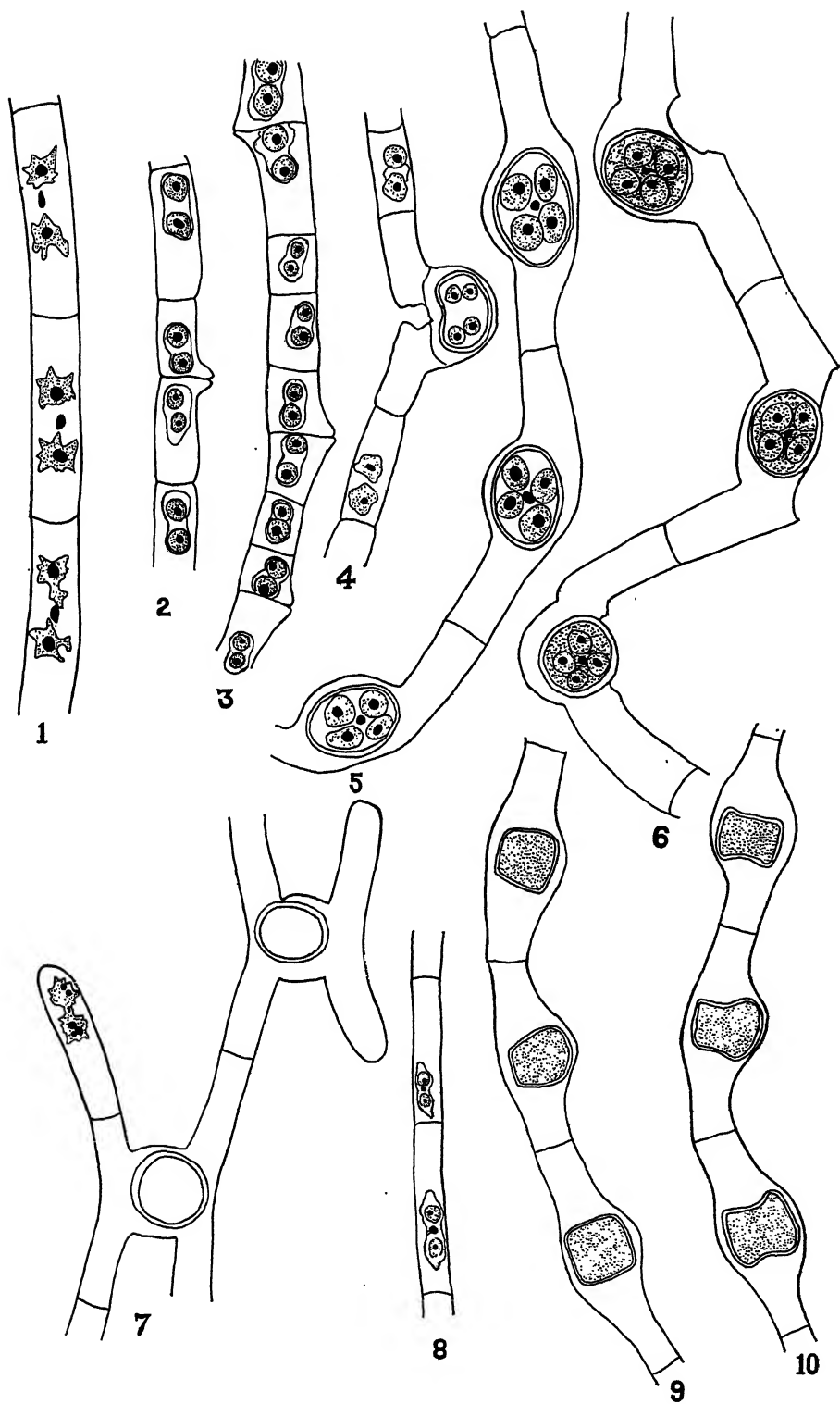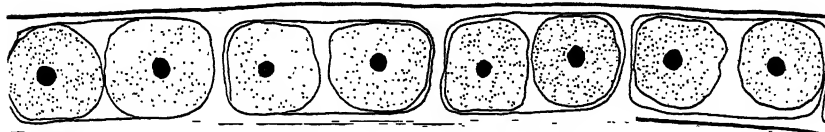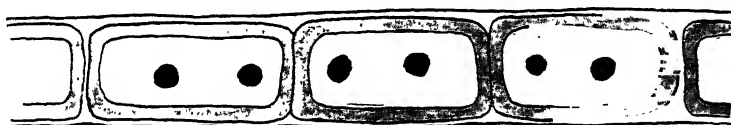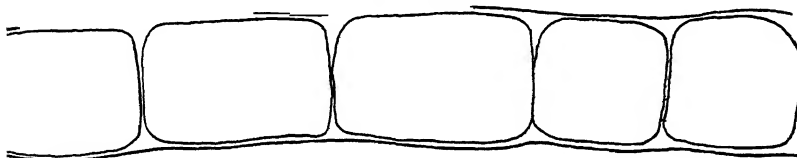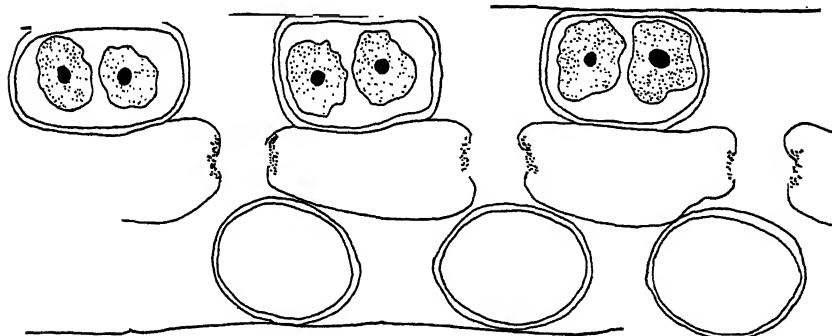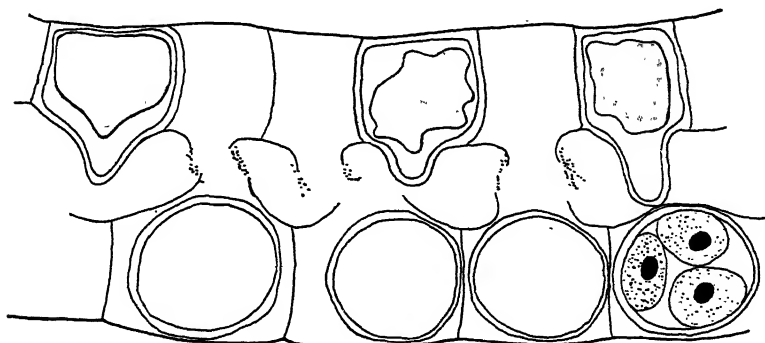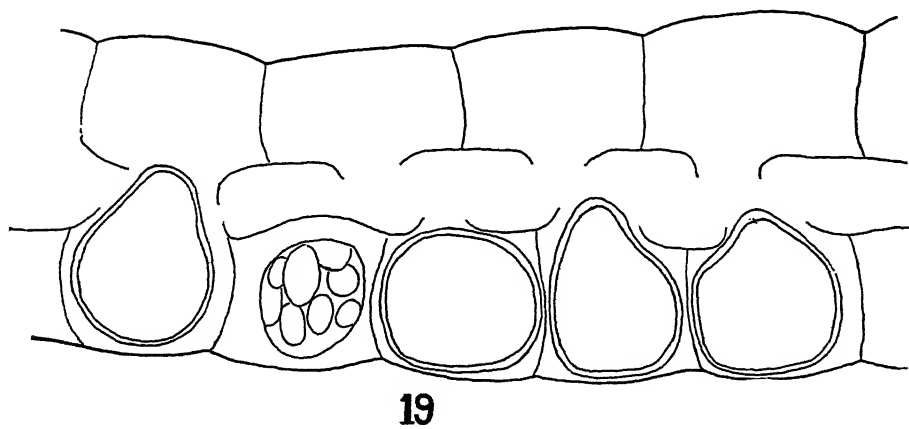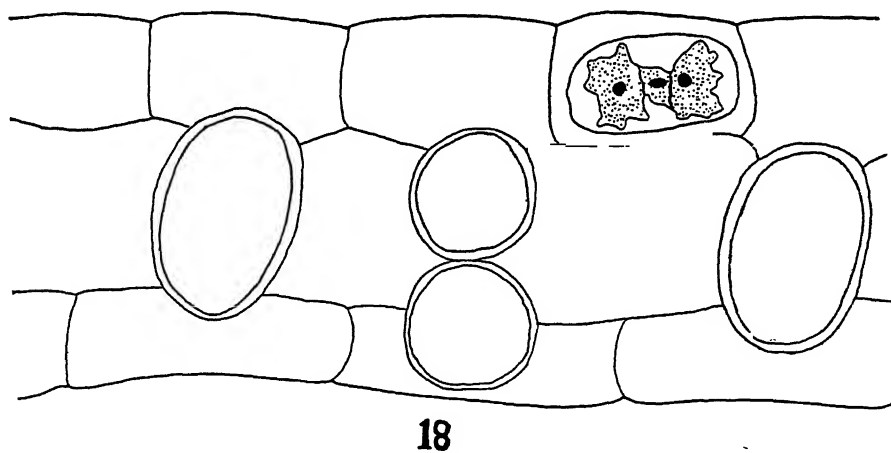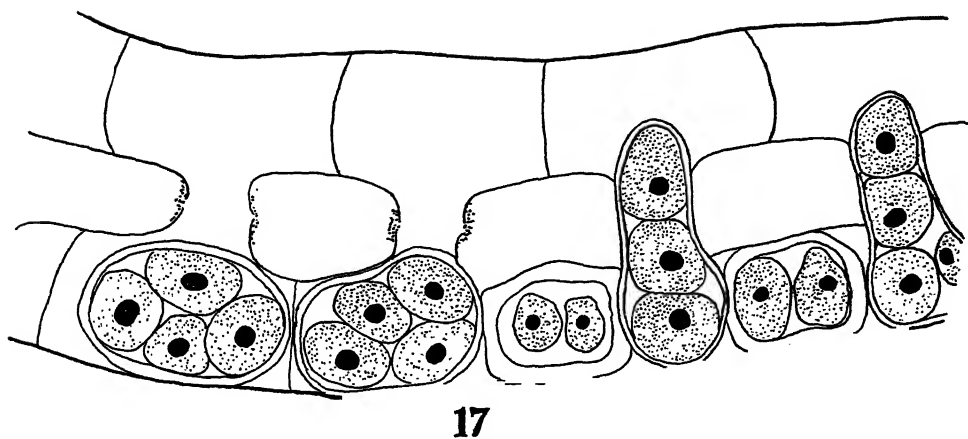
FIG. 13.—A filament showing a chain of brick-shaped parthenospores with two pyrenoids in each. ✕ 660.

FIG. 14.—A filament converted into a chain of orange-coloured parthenospores. ✕ 660.

FIG. 15.—Two filaments showing anisogamous conjugation. The male filament shows an alternation of male cells, and vegetative cells full of mucilage. ✕ 660.

FIG. 16.—This shows the abortive conjugation processes given out by the vegetative cells in the male filament. ✕ 660.

PLATE XIII.

*Zygnema giganteum* sp. nov.

FIG. 17.—Two filaments showing transitional stages between isogamy and anisogamy. ✕ 660.

FIG. 18.—Two filaments showing zygospores produced by isogamous conjugation and two azygospores. ✕ 660.

FIG. 19.—Two conjugating filaments showing pear-shaped zygospores. ✕ 660.

# A NOTE ON SOME ATTACHED FORMS OF *SPIROGYRA* FROM THE PUNJAB.

BY M. S. RANDHAWA, M.SC., I.C.S.

(*Saharanpur.*)

SPECIES of *Spirogyra* are generally free-floating forms but a few species however grow attached to the various substrata in the water.

Delf[2] has described *Spirogyra adnata* Kutz. and *Spirogyra fluviatilis* Hilse as forms occasionally producing rhizoids, and according to Kny *Spirogyra setiformis* Kutz. also sometimes produces rhizoids. *S. rivularis* (Hass.) Rabenh. (?) and *S. fluviatilis* Hilse var. *africana* Fritsch have been recorded by Fritsch and Stephens[3] as attached forms from Africa. Czurda[1] refers to *S. fluviatilis* Hilse and *S. Grossi* Schmidle as species growing attached. He has also figured the haptera of *S. fluviatilis* (1, Fig. 15). Iyengar[4] has described the haptera of a sterile species of *Spirogyra* growing in an artificial tank at Madras. Very recently Jao[5] has described a number of new species of *Spirogyra* from China and among them two species, *S. rhizopus* Jao and *S. rhizobrachialis* Jao, are described as developing rhizoids.

As far as the author is aware, there has been no record of any *fertile* species of *Spirogyra* from India growing in an attached condition. The following three fertile species of *Spirogyra* have been recorded by him from Northern India.

## Spirogyra affinis *Kutz.*

This alga whose usual mode of reproduction is by lateral conjugation (Fig. 1, *a*) quite often produces rhizoids from its cells. These rhizoids become closely attached to the filaments of an *Oedogonium* on which this alga is found as a common epiphyte in ponds. The hapterophores of this alga (Fig. 1, *b*) are bifurcated, and their ends are frayed and are not very different from those described by Delf[2] in *Spirogyra adnata*. Their size and lateral position indicate that quite possibly they are merely modified conjugation canals, though it is difficult to understand why these structures which are purely reproductive in function should subserve the function of fixation and support.
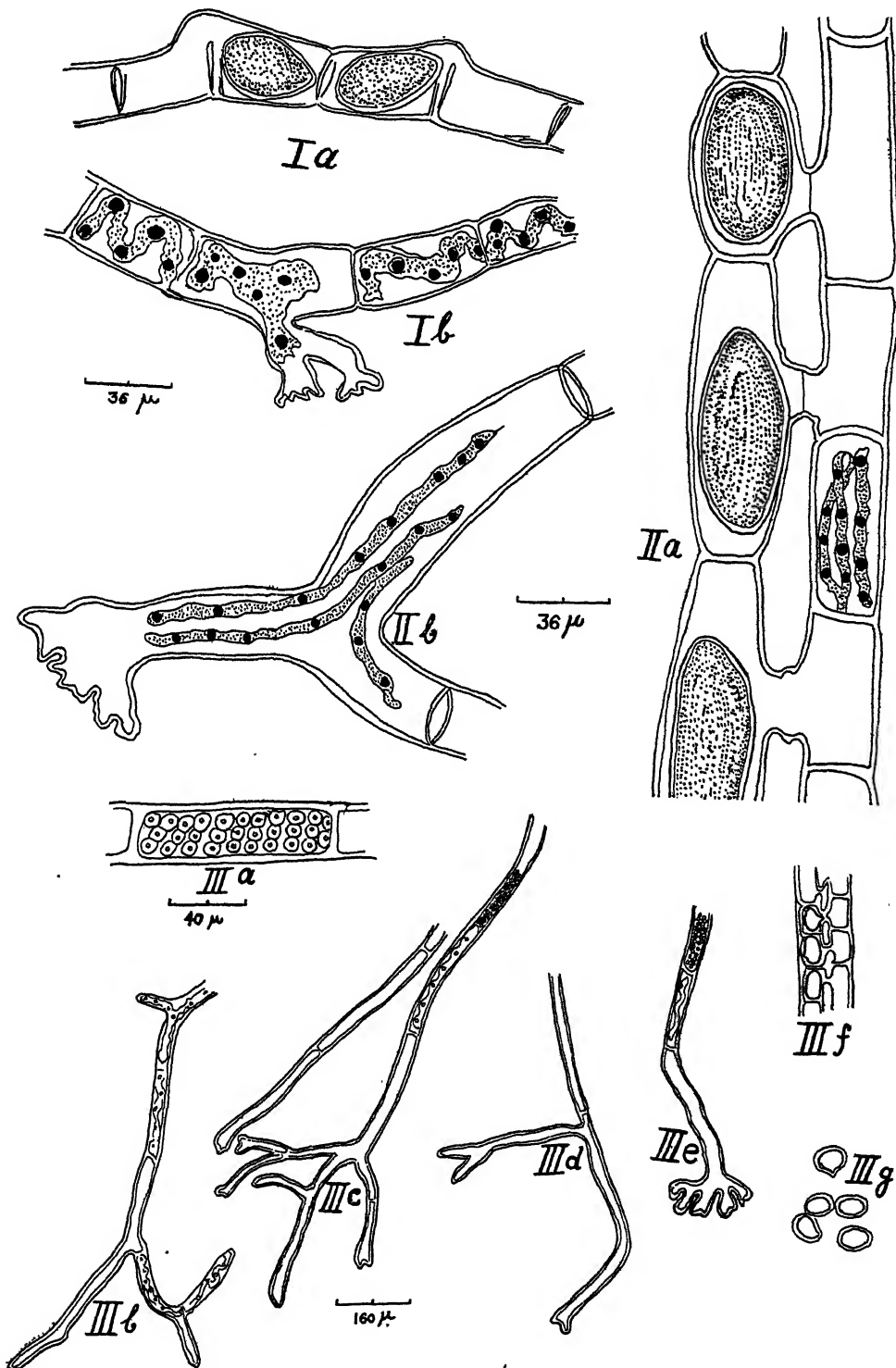
## Spirogyra dubia *Kutz.*

This alga is found in slowly flowing freshwater streams attached to water-plants by means of rhizoids which are very different from those of *Spirogyra affinis*. The rhizoids are not short and stumpy as in *S. affinis*, but are long and pillar-like (Fig. 2, *b*) and expand laterally and become frayed when they get attached to any aquatic plant. The chloroplasts in the rhizoids are never in the form of a spiral, but are in the form of palish green, very much elongated and thread-like bodies. The alga was conjugating freely (Fig. 2, *a*).

## Spirogyra *sp.*

This alga, which the author has not been able to refer to any known species and is probably a new species, was found growing attached to the stem of a water-plant in the big tank at Dasuya in the Hoshiarpore District. A similar attached form was also found by him in a sheet of water at Dhanauri, Tehsil Roorkee in Saharanpur District. The cells of the filament were 30 $\mu$ broad and about four times as long as broad. Owing to the very closely packed condition of the chloroplasts it was not possible to make out their number or the number of their spirals. Conjugation was observed in the upper parts of the filaments and ripe zygospores also were found in a few cells (Fig. 3, *f, g*). Some of them were long and dichotomously branched (Fig. 3, *b, c*) while others showed a dichotomously frayed disc at the bottom (Fig. 3, *e*). The former resembled somewhat the rhizoids of *Mougeotia* sp. figured by Pascher (**6**, p. 4, Fig. D) and those of *S. fluviatilis* (**1**, p. 14, Fig. 15, *a, b*), while the latter showed a certain amount of resemblance to the rhizoids of *S. fluviatilis* Hilse var. *africana* Fritsch (**3**, Fig. 22, B, D), *S. fluviatilis* (**1**, Fig, 15, *c*), *Spirogyra rhizopus* Jao (**5**, Fig. 11) and also to those of the sterile species from Madras (**4**, Pl. I, **3**, 4).

In this case and in the case of *S. affinis* the attached habit was developed in a distinctly still-water environment where the alga was in no danger of being washed away by a current of water. Iyengar's sterile species also was found by him growing in still-water in an artificial tank at Madras. So by no stretch of imagination can an attached habit be regarded as an adaptation to flowing water. Most probably the formation of rhizoids is a tactile response on the part of the filaments, and there is greater possibility of its successful manifestation in the form of rhizoids, in a still-water environment than in moving water.

My experience has shown that the fixed habit is quite common in the above species of *Spirogyra*, both in ponds and streams in Northern India, especially in the last mentioned form where it is a constant feature. A fixed habit with rhizoids is a distinct advance as compared with a free floating

habit ; and the species of *Spirogyra* which show this feature should be considered as more advanced structurally than the free floating ones.

Before closing, I must convey my sincere thanks to Dr. S. L. Ghose, Professor of Botany, Government College, Lahore.

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### EXPLANATION OF FIGURES.

FIG. 1.—*Spirogyra affinis.*  *a,* lateral conjugation ;  *b,* bifurcated hapterophores.

FIG. 2.—*Spirogyra dubia.*  *a,* conjugation ;  *b,* rhizoid.

FIG. 3.—*Spirogyra,* sp.  *a,* cell with dense chloroplasts ;  *b, c, d,* filaments with long and dichotomously divided rhizoids ;  *e,* filament with a dichotomously frayed disc at the bottom ;  *f,* conjugation ;  *g,* zygospores. Cells with degenerated and elongated chloroplasts are seen in *b, c* and *e.*

# CONTRIBUTIONS TO THE BIONOMICS, ANATOMY, REPRODUCTION AND DEVELOPMENT OF THE INDIAN HOUSE-GECKO, *HEMIDACTYLUS FLAVIVIRIDIS* RÜPPEL. PART I.

By Beni Charan Mahendra.

*(From the Department of Zoology, St. John's College, Agra.)*

## 1. *Introduction.*

THE selection of an Indian reptile for detailed description needs no apology. In most of our colleges and universities, the reptilian type prescribed for study is one of the Indian lizards, while the descriptions available for reference pertain to the common European lizard, *Lacerta.* This is an unfortunate state of affairs. The student dissects one type in the practical-room, and has to refer for help to the descriptions of another. Occasionally, his own observations do not tally with the descriptions in his text-books, and he is mostly left to himself to gain an imperfect, though not always faulty, idea of the anatomy of the group.

It is perhaps advisable to mention at the outset, why the house-gecko was selected for a comprehensive study in preference to such bigger types as the monitor lizard (*Varanus*) or the mastigure (*Uromastix*). The main reason is that I regard it as unreasonable to pay so much attention in our curricula to those types which we do not meet in our every-day life and to neglect the common inmates of our own houses. But apart from this consideration, there are a number of further advantages which a study of this lizard has over that of others. It can be more readily obtained; the cost of procuring it is small; the difficulties in studying it are hardly such as cannot be mastered by a conscientious student of average ability; and its anatomy, besides exemplifying the reptilian organisation as satisfactorily as any other type, abounds in many interesting features of its own. It belongs to what is generally regarded as a primitive family of the Lacertilia, and it is hoped that an intensive study of its organisation may add some valuable facts to the important question of affinities. Schmidt[1] (1934) says

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[1] *Turtox News*

that "there is a dearth of literature for reference on the general topic of lizard anatomy"; and Malcolm A. Smith[2] (1935) points out, "We are greatly in need of detailed accounts of the anatomy of the different groups of lizards." The present memoir, while primarily meant as an aid to university students, sets out also to fill up this gap in zoological knowledge and to throw light on the interrelationships of the *Gekkonidæ*. Interspersed here and there throughout the text, I have included the compendium of a huge number of recent papers on reptiles in order to give the proper perspective and comparative value to the facts I deal with. This is essential, because otherwise the value of the new facts dealt with cannot be brought in relation to those already known.

As might be imagined, the preparation of the present work has involved a painstaking search through almost all the more important papers relevant to the subject, and I have devoted more than three years at it. I have not only derived some material and many suggestions from various sources, but have also been alert to verify facts by my own observations. I do not claim to be infallible, nor can I profess to have gone through the entire range of herpetological literature—a task impossible for me on account of its magnitude; but I have taken great pains to make this work as accurate as I could.

## 2. Systematic Position.

As is fairly well known, the present-day Reptilia can be divided into four orders: (1) the *Rhynchocephalia*, (2) the *Squamata, Lepidosauria*, or *Plagiotremata*, (3) the *Crocodilia* or *Loricata*, and (4) the *Chelonia* or *Testudines*. Of these four orders (or according to some, sub-classes), the *Squamata*, which

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[2] In a letter, addressed to the author, dated June 3, 1935.

consists of both the *Ophidia* (*Serpentes*) and the *Lacertilia* (Sauria), is charac-
terised by Sedgwick (1905) as follows :

"Procœlous, rarely amphicœlous vertebræ, and with horny scales ;
sacrum of two vertebræ or absent ; ribs single-headed ; abdominal ribs
absent. Quadrate movable, attached to the skull by its proximal end only ;
lower temporal arcade absent ; palate with many vacuities ; pterygoid
not reaching to vomers" (p. 334).

This definition, though giving a fairly general idea of the group, cannot
be said to be strictly accurate. Stannius, as far back as 1856, mentioned
the presence of abdominal ribs in *Platydactylus guttatus* ; Fürbinger in 1900
gave a good comparative account of them in many lizards ; Beddard re-
ported on their presence in *Tiliqua* in 1904, and in *Trachysaurus rugosus* in
1906 ; and more recently, Camp in 1923 says that the Parasternum "reaches
a maximum extent among the subterranean Scincoidea........It also appears
in a slight degree among all known surface-living terrestrial Scincoidea,
and so far as known among the Anguimorpha, only in the Chamæsaurinæ."

Besides these exceptions to Sedgwick's definition, I might mention
that the pterygoid in one case at least (Beddard, 1905) has been described
as reaching the vomers ; and that recently, I (Mahendra, 1936) have re-
corded a case in which the other head of the rib appears to be present. How-
ever, the presence of a transverse cloacal opening, the absence of the lower
temporal arcade, the movable nature of the quadrate, and the paired nature
of the copulatory organs, serve sufficiently to distinguish this order from
the others.

The Indian house-gecko (*Hemidactylus*) belongs to the family Gekkonidæ,
which as now constituted comprises also the Eublepharidæ and the Uropla-
tidæ (Smith, 1933).

### 3. *History of the Genus and the Species.*

Boulenger (1890) thought that the genus *Hemidactylus* was first insti-
tuted by Gray in 1825 ; but according to Malcolm A. Smith (1935), the
first record of this genus dates back to Oken (*Isis*, p. 1183) in 1817, who seems
to have framed it on the basis of Cuvier's Hemidactyle (*Règne Anim.*, ii, 1817,
p. 47).

As for the species selected for detailed study here, it was long known
as *Hemidactylus coctæi* under the impression that Dumeril and Bibron were
the first to describe it in 1836. Cantor (1847), Günther (1864), Theobald
(1876), Murray (1884), Boulenger (1885; 1890), Stoliczka (1872), Blanford
(1876) and several other authors have called it *H. coctæi* in their
works. It was Boulenger (1912) who pointed out that the real credit for

the institution of this species belonged to Rüppel (1835), and that the name *H. flaviviridis* should be preferred to *H. coctæi* according to the law of priority of nomenclature. Since 1912, therefore, the species is universally known as *H. flaviviridis* Rüppel.

### 4. *Geographical Distribution.*

The family *Gekkonidæ*, to which the Indian house-gecko belongs, is practically cosmopolitan in its distribution, being found in tropical and semi-tropical regions all over the world. Specimens belonging to this family "are frequently transported in the cargo of ships, and the wide distribution of certain species of *Hemidactylus, Gehyra, Hemiphyllodactylus, Lepido-dactylus, Platyurus*, and *Gekko* is no doubt due to this cause" (Smith, 1935). The genus *Hemidactylus* has also a wide range. It consists of more than 60 species which occur in Southern Europe, Southern Asia, Africa, tropical America and Polynesia. Of these numerous species, 17 are known to occur in British India (including Burma and Ceylon), *H. flaviviridis* being common in Northern India, "though it does not occur east of Bengal, nor, with the exception of the individuals recorded from Bengal, south of lat. 20°" (Smith, 1935). This species extends westwards from Northern India through Persia and Arabia to the shores of the Red Sea.

### 5. *Fossil Lacertilians and Gekkonids.*

Compared to the numerous *recent* genera and species of Lacertilia, the number of fossils known so far is almost insignificant. "The oldest, but incompletely known, form is *Macellodon* from the Upper Jurassic (Purbeck Beds),"[3] but its remains (fragmentary jaws and proccelous vertebræ) "are too imperfect for accurate determination..... Even the known Teritary fossils are very fragmentary, and belong for the most part to existing families. From the Lower Eocene of Wyoming representatives are known of the *Varanidæ (Tinosaurus), Anguidæ (Glyptosaurus, Saniva, Xestops), Iguanidæ (Iguanavus)*, and *Chamæleontidæ....... *The Miocene also yields a number of Lacertilian fragments identifiable with recent genera."[4] Apparently, this order of Reptilia has attained a far greater development only latterly, in the Tertiary Period.

In 1903, Broom described a small but fairly well-preserved skull from the Triassic of South Africa under the name *Paliguana whitei* and he claimed that it was the oldest known lizard. In 1914 Watson examined the specimen and doubted the validity of Broom's view; while Boulenger in 1918

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[3] Sedgwick, Adam, *A Student's Text-book of Zoology,* 1905, 2, 348.

[4] Zittel, Karl A. von, *Text-book of Palæontology* (translated and edited by C. R. Eastman), 1902, 2, 162.

considered it "problematical". In 1923, Camp made the suggestion that *Paliguana*, "apparently a true lacertilian", shows affinities to the Iguanidæ, Agamidæ and Gekkonidæ. In 1925, however, Broom restudied the specimen and felt it advisable to "remove *Paliguana* from the Lacertilia as at present defined," although he remarked, "In *Paliguana* we have a form which though not a lizard, is nevertheless almost a lizard," and that "from *Paliguana* to the lizard is only a very short step and one easily understood."

As regards the fossil Gekkonidæ, Camp (1923) says, "No fossil geckoes are known from the Tertiary, but von Mayer (1860) has excellently described and figured an important form, *Ardeosaurus brevipes*, from the Lithographic stone of Eichstatt. The age is Tithon, a formation which has been lately assigned to the Jurassic, but some question this and would place it in the Cretaceous.

"Lydekker (1888) has assigned Ardeosaurus to the Rhynchocephalia. Nopcsa (1908) calls the genus a ' Scincoid ' without stating reasons. The small reptile is unquestionably a lacertilian as von Meyer supposed.....The only existing lizards which show the combination of characters, to be seen in Ardeosaurus, are the geckos," but there are differences "which establish the Ardeosauridæ as a separate family of the Gekkota, perhaps ancestral to the geckos."

In this connection, I am indebted to Mr. D. N. Wadia, Palæontologist, Geological Survey of India, for the following note :—

"Fossil remains of Lacertilia are rare in India and are mostly fragmentary. *Varanus* has been known from the Pliocene (Upper Siwaliks) of India (Lydekker: *Pal. Ind.*, Sers. X, III, Pt. 7, pp. 209–240, 1886, Siwalik Crocodilia, Lacertilia and Ophidia). There is no special reference to the occurrence of fossil Geckonidæ in the Siwaliks, though remains of Crocodilia and Chelonia are most prolific. Fossil *Varanus*, with some other lizards, occurs in the Pleistocene deposits of the Karnud caves (*Ibid.*, IV, Pt. 2, pp. 23–58, 1886). Falconer has described some fragmentary fossil lizards from the Siwalik hills (*Palaeonl. Memoirs*, Vol. I, Plate 32, London, 1868).

"The following work may be of use, "Zur Kenntniss der fossilen Eidechsen," *Beitr. Palæon. u. Geol. Osterreich-Ungarus*, Vol. XXXI, p. 33, 1908."

### 6. *Material and Technique.*

All the specimens used in the present investigation were collected at Agra and properly identified. The study of the habits and life-history of the house-gecko has necessitated  not only careful sustained observations on it in its natural environment of the house, but also the actual rearing and keeping of it under controlled conditions of the laboratory. The latter has

been made possible through the use of a specially constructed large cage, which, besides providing comfortable lodging to the captive lizards, gives many conveniences to the observer and makes it possible, amongst other things, to secure enough number of eggs to work out the development. A more detailed account of the development of these creatures will be published elsewhere in course of time.

The cage employed (Plates XIV and XV) is exceptionally commodious, being 3½ ft. high, 3½ ft. wide and 6 ft. long. Its front is made of four large glass panes, with sliding wooden doors which can be drawn up and down to any height required and thereby not only admit or cut out light as needed, but also make every place inside the cage open to observation. Each side wall of the cage has a window, 1½ ft. × 1½ ft. in size, with three removable doors, one of fine wire-gauze, the other of glass and the third of wood. Usually the wire-gauze door remains in position to give ventilation to the cage ; but whenever required, the other doors can also be fixed up readily. The opening of all these doors allows the servant to get into the cage in order either to clean it, or to catch some required specimen. On the top of the cage is a trap-door to drop insects inside ; and all along the ceiling there are twelve drawer-shaped niches, 1½ ft. long, 1½ in. wide and 1½ in. deep. These niches open inside the cage and allow the lizards to hide in, when they want to. They have two covers above, one wooden and the other (which is below the wooden one) of glass ; and they can be opened from above. The captive lizards lay eggs only in these niches and there is no difficulty in removing the eggs. Almost every part of the cage can be locked ; and a shallow large dish is kept inside, filled with drinking water.

For securing the eggs in adequate numbers for developmental work, several methods were tried, but the most successful proved to be the collection of a hundred or more large females during the breeding-season, especially one or two fortnights after the act of copulation had started, and keeping these individuals in the cage. The row of niches was regularly examined both morning and evening each day, and the eggs were removed as soon as they were discovered. Now and again it was found that some house-geckos may even eat their own eggs, but this fact was probably due to the artificial conditions inside the cage, more particularly to the overcrowding of specimens and the lack of adequate supply of food ; more often than not, the encaged specimens had to be kept in a rather semi-starved condition. This, however, does not interfere with the getting of normal, *hatchable* eggs.

At first, the eggs were incubated by keeping them buried in moist sand or earth, which was daily besprinkled with a little water to keep it damp.

This was done with the feeling that moisture is one of the necessary conditions of a good hatch in this creature also, as it is in fowls and in other reptiles.[5] But ultimately it was discovered that the eggs of the gecko develop as successfully in the room atmosphere as inside the moist earth, and therefore incubation in moist earth was given up. In nature, the geckoes lay their eggs in some hidden crevice or hole in the wall and do not care in the least about them. The eggs incubate on account of the warm atmosphere around them.

### 7. *General Habits.*

The house-gecko is both nocturnal and secretive in its habits. It usually remains hidden during the day, but as the shades of evening approach, it stirs out of its hiding-place to seek for its prey. It loves warmth, and is absent from the colder parts of the globe. When the temperature is comparatively high (March to September), it is found in houses in very large numbers ; but with the approach of winter, it retires to holes or crevices and lies there in a semi-torpid condition. Throughout winter, house-lizards are rarely seen, but as the temperature again rises, they come out of their retreats and even bask in shaded sunlight. Extreme chill is fatal to them.

### 8. *Food and Feeding Habits.*

The house-gecko is mainly insectivorous. It eats house-flies, mosquitoes, crickets, moths, butterflies, beetles, caterpillars and similar other small insects ; but under exceptional circumstances, especially when it is famishing, it may even turn a cannibal and eat smaller members of its own species (Rao, 1924). McCann (1926) mentions the case of a house-lizard which was fond of eating sugar.[6] Loveridge (1920), speaking of *Hemidactylus mabouia* Gray, adds spiders to the menu and also says, " One particularly gorged specimen had a big brown cockroach 40 mm. long in its stomach." In another paper (1923) he includes polydesmids, tsetse-flies, mantis, centipedes, male "siafu" or soldier ants and acridians in the dietetic records of this very species. Cott (1934), besides reporting the presence of such expected details of dietary as cockroaches, earwigs, beetles, lepidopterous insects, homopterous bugs, orthopterans and muscidflies, mentions the peculiar item, "the digested remains of a young tree-frog, possibly *Hyperolius* sp. This last item," he says, "is rather surprising, and it would be

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[5] Asana (1931), working on the eggs of *Calotes versicolor,* incubated them by embedding them in "moist rather sandy earth" and sprinkled water on it "every twenty-four hours, in the early stages . . . . to keep it moist". Moistening of the reptilian eggs is generally regarded as necessary for a good hatch.

[6] Malcolm A. Smith (1935, p. 27) says: "Some of the House-Geckoes will take grains of rice, and they also appreciate sugar. Water is taken by lapping up with the tongue, and they are said to consume large quantities when they can get it."

interesting to know whether small tree-frogs are frequently preyed upon by this[7] or other species of Gecko." Several times I have fed the encaged house-geckoes with earthworms, and it appears to me that they are not fastidious about the species of their animal food as long as it is handy. The movements of the prey apparently attract the attention of the geckoes,[8] and they dart on to catch it.

The skill and agility which the house-gecko showes in hunting its prey is remarkable. When it observes an insect fluttering about, it hastens to the spot, slows down its pace on nearer approach and finally sits 'crouched', ready to pounce upon the unsuspecting creature in an unguarded moment. Now and again, it steals a step or two nearer. Its remarkably depressed body lies so flat against the wall that there is hardly a warning shadow; its attitude is of complete attention. All of a sudden it darts forwards, snaps[9] at the insect and holds it struggling in its mouth. Lizards do not wait for their prey to die, but start swallowing them as soon as they catch them. If the prey is large, the lizard might strike it right and left against the wall before beginning its meal; but it rarely loses its fatal grip on the insect.

How far the house-lizard (*H. flaviviridis*) exerts a sense of selection amongst the creatures that it preys upon, is not definitely known, but some observations show that it generally excludes dangerous insects from its menu. It appears, for instance, to refrain from attacking wasps, and Loveridge (1923), gives the following similar examples in connection with *H. mabouia* Mor. :

"A fly (*Negritomyia maculipennis*), which is an excellent mimic of one of our wasps, was crawling on a white and lighted ceiling at 8 p.m., when I observed a gecko stalking it. When the gecko was just about the right distance for a spring the fly gave a buzz, and the lizard, after studying it a moment longer, withdrew."

"At sunset I observed a gecko on the gauze facing upwards to a large blue hornet, the hornet adopted a menacing attitude and then flew a few inches up the gauze and again settled, the gecko ran after it but halted an inch away and did not attack."

Sometimes, the house-gecko might attack a dangerous creature to its own detriment, and learn a lesson thereby. There is on record the case

[7] *Hemidactylus mabouia* Mor.
[8] *Cf.* Burt, *Jour. Kansas Ent. Soc.,* 1928, 1 (3), 50–68.
[9] Ekambaranathan (1930) is mistaken when he says, "it runs up quickly towards the prey, and shoots out its tongue; the prey sticks to it like a fly to fly-paper; the tongue is quickly drawn into the mouth with the prey".

(Loveridge 1923, pp. 938–939) of a gecko attacking a solpugid (*Solpuga darlingi*) and later, being "found to be flinging itself about and squirming over in an attempt to rid itself" of it. The latter "was holding the gecko in its jaws, seizing the head between eye and ear. The skin was all gone from this area and there were signs of bites on the right side and near the base of the tail."

. Like many other reptiles, house-geckoes have . remarkable powers of going without food. Unless properly kept, they may refuse food in captivity. According .to Baini Prashad (1916), "they are very shy, and not at all sociable in captivity.[10] Though a great variety of food was tried in the case of some lizards in captivity, yet they refused all food, and became quite emaciated, all the bones were to be seen through the skin, practically no muscles being left..... The various changes of diet tried in this case were house-flies, mosquitoes, various other insects, caterpillars, earthworms and meat, but with no success. In captivity the lizards pass out small hard whitish pellets as their fæces." The difficulty experienced in feeding house-geckoes in this case was probably due to their having been kept in cages, which were both small in size and open to public exhibition. These creatures have a nervous temperament and resent much tampering. They can fast a great deal. I have known them fast as long as five or six months and ultimately die of starvation.

The insectivorous nature of the house-gecko makes it a useful creature · to humanity. It kills considerable numbers of vermin in our houses and is an important check on their over-population. Giles regards this reptile "as a valuable destroyer of mosquitoes in houses,"[11] and Miyamoto (1930), in a statistical study, finds that *Gecko japonicus* and *Hemidactylus bowringii* catch every day as many as 49–59 and 43–48 specimens of blood-engorged females of *Culex fatigans* respectively. Besides gnats and mosquitoes, the house-gecko controls the numbers of such other harmful insects as the house-flies, crickets, cockroaches, etc. When this lizard is absent or rare in a particular locality, the noxious insects are apt to multiply so much that human habitation becomes extremely inconvenient, if not altogether impossible.

### 9. *Ecdysis or Sloughing.*

Like snakes, the house-gecko also sheds its skin—a process which is known as *ecdysis* or *sloughing* (Plate XVI, Fig. 3). Before this process is

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[10] Contrast this opinion with Malcolm A. Smith's statement (1935, pp. 27–28) : "House-geckoes can be readily tamed and will learn to come to the table and take food from the hand."

[11] Giles, 1902 (quoted by Baini Prashad, 1916). I have not been able to verify this reference.

complete, the lizard becomes very lethargic and lazy, but when the skin has been shed it is once again quite active. Its colour also is more pronounced. For removing the slough, it either rubs itself against some rough surface, or tears the dead skin off by means of its mouth and fore-limbs. The skin does not come off in one entire piece, but is generally shed in several pieces or flakes. Two or three times I came across a house-gecko peeling off its slough piece by piece and eating it, but whether such a disposal of the slough is universal or not, cannot be definitely stated.

The first sloughing in the case of *H. flaviviridis* and *H. brooki* takes place soon after their emerging from the egg. From that time onwards the process occurs periodically once or twice a year, but the interval between one sloughing and the next is not constant. The slough is white and delicate in appearance, and shows the scalation well.

As far as is known to me, the factors initiating and controlling the sloughing process in lizards have not been fully worked out. The experiments of Noble and Bradley (1933), however, seem to indicate to some extent that both the thyroid and the hypophysis play some rôle in this process. Although neither thyroidectomy nor hypophysectomy prevent the 'molting' entirely, they do lengthen the period between successive molts. As Noble himself sums up the results of his work, "thyroidectomy did not delay the appearance of the molt immediately following the operation but affected all later molts. If not more than 6 follicles remain after thyroidectomy, the effect is the same as in complete thyroidectomy. Injections of thyroxin, 1 to 10,000 and later 1 to 30,000, given intramuscularly to thyroidectomised lizards on alternate days bring a return of the molt to its normal periodicity. However, neither injections of thyroxin nor implantations of fresh lizard thyroid increase the frequency of molt in the intact lizard. Completely hypophysectomised *H. brooki* turn a pale grey and retain this colour permanently under varying environmental conditions. Lizards with fragments of the pars intermedia remaining turn a slightly dark tone under conditions where the controls are very dark grey. Removal of the pars anterior of the pituitary alone has the same effect on delaying the molt as removal of the whole gland. The lengthening of the interval between molts may be due to a lowering of the metabolic rate and not to any direct action of either the anterior pituitary or the thyroid on the molt mechanism."

## 10. *Fidelity to Sites in the House.*

Although it might be widely known that the house-gecko hardly ever ventures abroad from its own locality, most persons do not know that even in the same house, it remains true to its own accustomed site and does not

migrate to another part, unless compelled to do so.   One gecko might stick to a place behind a book-shelf, another remain in a particular crevice in a wall, a third inhabit the cellar, and so on ;  all being true to their own sites.

Flower (1933) gives the following interesting instance in connection with a different genus of gecko :

"A Fan-footed Gecko[12] brought in from the desert was turned loose in my room; though both by day and night the doors and windows of the room were more often open than shut, the gecko never went into any other room and was never observed to go out of doors, even into the verandah.   Some months later as I had to move to another house about half  a  mile away, I took the gecko with me and turned it loose in my new room where it ran about the walls and furniture and never went out.   About three months later I returned to the original house taking the gecko with me and again turned it loose, and again it remained in the room where it had been liberated, until it disappeared some time in the third year after it had had to leave its desert home."

How far the genus *Hemidactylus* can be tamed and kept as pet, we are not sure, but in general, as pointed out by Smith (1935, pp. 27–28), "House-geckoes can be readily tamed and will learn to come to the table and take food from the hand."   Usually, they are shy of human society.

### 11.   Tail and its Autotomy.

The tail of the house-gecko is extremely fragile, and at times of danger, serves as a valuable device for protection and  escape  from  its  enemies. A moderate shock breaks this part from the rest of the body, and it starts twisting and writhing and jumping about, mimicking the movements of an animal in pain.   The enemy of the lizard takes the simulating tail to be the whole animal, and thus deluded, lets the tailless trickster escape not much harmed.   Not only has the tail the power of jumping about by itself, but even when its activities have subsided, a slight interference makes it resume its contortions.

It might be supposed that the point at which the tail breaks off is inter-vertebral, and that it is the ready separation of the caudal vertebræ from each other which allows the tail to drop off from the rest of the body.   As a matter of fact, however, the break never takes place between two vertebræ, but occurs through the middle of a single vertebra (Fraisse, 1885 ; Brindley, 1898 ; Tornier, 1897 ; Gadow, 1901, etc.)   The tail vertebræ are especially adapted to this purpose.   They are actually  divided  into  an  anterior  and

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[12] *Ptyodactylus hasselquistii* (Donndorff).

a posterior half by an unossified vertical plane[13] that passes through their middle, and the tail always breaks in the region of this plane.  Even the scalation of the tail, which is segmented in appearance, and the nature of its vascular supply,[14] show adaptations for autotomy.

The structure of the tail and its mechanism for autotomy have both been admirably described by Woodland (1920), who even compares the case of *Hemidactylus* with that found in *Sphenodon* and *Pygopus* and contrasts it to that of a non-autotomous lizard, *Calotes*.  Amongst the more important adaptations to autotomy found in *Hemidactylus* might be mentioned the presence of segmentation in scalation, the segmental subdivision of the subcutaneous fat layer and the caudal muscles by planes of non-cellular matrix, the division of the caudal vertebræ by cleavage planes, the presence of sphincters[15] in the caudal artery just anterior to each autotomy plane, and the constriction of the caudal vein at the regions for autotomy.  Woodland records the presence of a Reissner's fibre inside the spinal cord ; and although he does not speculate on—or try to discover—its function in autotomy, it might perhaps be supposed that it has got something to do with the self-directed movements of the autotomised part, as well as with the pre-autotomy flexion of the tail.  In the case of fishes (Nicholls, 1917), the free ends of the Reissner's fibre, when it breaks, " recoil sharply to form tangled knots or 'snarls' ",   thereby leading to a twisting away and withdrawal from the

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[13] "Gadow (p. 494) describes this as a 'cartilaginous septum . . . which coincides exactly with the line of transverse division of the vertebra . . . where the tail breaks off and whence it is removed'.  This is a mistake; the vertebral plane of cleavage simply consists, . . . . like the planes and lines of cleavage already mentioned, of a sheet of non-cellular hyaline substance which is continuous with those separating the other tissue of adjacent segments; also the plane of cleavage lies immediately behind the transverse process of the centrum, which is therefore not affected by autotomy and remains projecting from the posterior surface of the portion of tail retained by the animal . . . I have verified these statements in numerous longitudinal and transverse microtome sections; also in hand-cut sections, these latter proving, in virtue of their thickness, more useful on the whole than the former."—Woodland, 1920, pp. 82–83.

[14] Woodland (1920) describes the presence of sphincters in the caudal artery as a means of avoiding hæmorrhage after autotomy, and mentions that the caudal vein is constricted in front of each autotomy plane.

[15] In describing these structures in *H. flaviviridis*, Woodland (1920) says, "as far as I am aware, this is the only instance yet described of a sphincter muscle being developed on a blood vessel" (p. 76).  I might, however, mention, that Gratiolet discovered circulatory sphincters in the blood-vessels of the hippopotamus in 1860, and that Irving (1934) and Parker (1935) are inclined to regard them in this mammal as "a means . . . of restricting the circulation in such a way as to limit temporarily the active flow of blood to the anterior part of the animal, particularly to the heart and brain, and thus to economize the store of oxygen in the lungs when the animal submerges".  Of course, the function of these sphincters in *Hemidactylus* is different.

point of breakage. If the same thing happens in *Hemidactylus*, it is not unlikely that it may account also for the autotomtic movements of the separated tail. According to both Dendy (1909) and Nicholls (1913, 1917), the function of the Reissner's fibre is "to control automatically the flexure and pose of the body," but the fact that their views have not taken into account the case of autotomous lizards, in which the tail exists merely to break away in cases of danger, makes it necessary to undertake experiments on the functioning of this fibre in lizards, and I hope to investigate this problem fully in future.

## 12. *Regeneration.*

The power of regeneration possessed by the caudal region in *Hemidactylus* is truly remarkable. Almost always the mutilated tail grows again, but the point where the original tail broke off remains more or less distinct. Sometimes lizards may be met with, having a bifid, or even trifid tail (Brindley, 1894; Brindley, 1898; Stuart, 1908; Loveridge, 1920; Loveridge, 1923; Hora, 1926; Das, 1932; etc.).

The regenerated tail differs from the original one in many important features, mainly in "the total absence of any signs of segmentation.....either on the surface or in the internal structure" (Woodland, 1920). Its scalation shows no lines of cleavage at all. Dorsally, there is a "uniform covering of the usual small scales" throughout; laterally, the scales are rather larger; and ventrally, there is a longitudinal series of large laterally-elongated scales in the middle line.

As regards the significance of the difference in scalation between the original and the regenerated tail in lizards, Boulenger (1888), who made observations on the tails of a 'Geissosaurine' teiid, *Gymnophthalmus* and an anguid, *Ophisaurus*, believes that "in some cases, the aberrant scaling of the reproduced tail is a reversion to an ancestral form." Werner (1896) supports this view on the basis that "in certain geckoes having rows of larger tubercles on the tail the reproduced tail developed the uniform granular scaling found both on the embryo and in certain other geckoes believed to be more primitive on account of the non-laminate condition of their toes."[16] Tornier (1897) and Woodland (1920) both take exception to Boulenger's view.

Internally, the regenerated tail in *Hemidactylus flaviviridis*, has the subcutaneous fat layer continuous throughout its whole length, there being no lines of cleavage at all. The muscles, twenty to thirty in number, run in a straight line all along and have no special connections in their course.

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[16] The quotation is from Camp, 1923, p. 398.

The substance of the submuscular fat bands is not divided by transverse planes. A thick-walled cartilaginous tube takes the place of the vertebral column, neural spines and hæmal arches both being absent. Inside this tube is a much attenuated extension of the spinal cord, practically consisting of a continuation of the cellular lining of the canalis centralis, with little or none of the external nerve fibre substance, and giving off no nerves at all into the regenerated tail. The caudal artery has no sphincters, and the caudal vein is uniform all along in its diameter (Woodland, 1920).

The skin of the house-gecko is thin and delicate, and it is much liable to be scraped off through accident or harsh handling. Its accidental removal, however, does not lead to a bleeding wound, and it rapidly regenerates to form the normal granular scalation. The regenerated granules are at first much smaller than the ordinary ones, but later on they attain more or less to the normal size.

How far the toes of the house-gecko have the power of regeneration has not yet been discovered, and a consultation of the relevant literature shows that no work in this respect has so far been done on *Hemidactylus flaviviridis*. I hope, however, to perform a series of experiments in this connection and to publish the results in the near future.

## 13. Hibernation.

Our knowledge about the causes, habitat, conditions and physiology of hibernation in Indian reptiles is nothing but meagre, and it is extremely necessary, therefore, to make detailed observations and experiments—both in the laboratory and in the natural environments—to fill up this gap. As Pocock (1910) rightly points out, "owing to the extreme difficulty of keeping wild animals under observation in their natural haunts for any lengthened time, it is almost impossible to get accurate knowledge of the details of this state of existence. In a general way it is known, or assumed from their disappearance, that certain species retire to winter quarters in particular districts, but on such important points as whether the winter sleep is continuous or interrupted, light or profound, assured information is for the most part not forthcoming. This is true even of familiar species inhabiting Europe and North America, which have been objects of study for many years. It is still more true of species occurring in countries uninhabited or rarely visited, especially in winter, by naturalists interested in such questions."

Last winter, three adult specimens of *Hemidactylus flaviviridis*, which remained in my cage after the rest were used up for anatomical studies, were kept under observation from time to time. They all hid themselves in the darkness of the breeding-drawers, and hardly ever came out. Although

profound torpor seemed never to have set in, they were in a state of extreme lethargy, and did not mind even handling. The breathing was considerably slow, as could be ascertained by noting the movements of the throat and the body-cavity; and alimentation and excretion were both, as a rule, suspended. The response of the pupil to increased light, however, was normal; and it was found possible to stir up these creatures from their state of sluggish quiescence by keeping them in warm, sunny surroundings.

### 14. Age.

The maximum recorded age in captivity for the species *Hemidactylus brooki* (Flower, 1925) is 1 year, 1 month and 10 days; and that for the species *H. turcicus* (Flower, 1925) 2 years, 5 months and 11 days (the latter lizard having been still alive after this period). We have no similar records for the species *H. flaviviridis*, but as far as can be ascertained, the genus *Hemidactylus* (barring accidents) attains, in favourable natural conditions, an age much higher than the ones given above for captivity, probably as much as four to five years. Further observations on this point, however, are necessary.

### 15. The Breeding Season.

The copulation of the house-gecko (*Hemidactylus flaviviridis*) generally starts in March in the northern parts of India and continues for several months. Judging from actual observations of living animals, the breeding season for these lizards normally extends from the end of February or the beginning of March to late September, or even up to October[17]; but so much seems to depend in this matter on climatic conditions that one hesitates to be dogmatic about dates. At Agra, the maximum number of early young ones of *H. flaviviridis* were obtained in the months of May and June (1935), which means that the maximum activity of the gonads is probably evinced during April and the earlier weeks of May. The breeding season of *H. brooki*, however, starts later than that of *H. flaviviridis*. Curiously enough, copulation even

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[17] Baini Prashad (1916, p. 838) states that the breeding season of this lizard extends from the beginning of March to the end of May. Asana (1932) states that "the breeding season, the progressive and regressive cycles in the gonads of *Hemidactylus* . . . follow those of *Uromastix* in its sexual cycle". Later, Asana, in a letter addressed to me and dated March 18, 1936, says: "From my observations on some slides and the study of the size of the gonads of dissected specimens collected during the last 4 or 5 years, I am inclined to think that the onset of the breeding season on this side (*viz.*, Ahmedabad) is considerably earlier; I should put it in October or November. Because, in December, I have seen testes reaching their height of development and growth, all tubules mostly packed with sperms. I am not sure about ovaries. Regression in testes starts much earlier. I am inclined to think that they have declined in April, even in March." In fairness to Mr. Asana, I must mention that he is still working at the problem and is both testing and confirming his conclusions.

in the same locality starts a fortnight or so earlier in the congested centres of population than in the open bungalows in the suburbs. In the former places, the closely-built stone-and-mortar houses offer the necessary heat conditions *sooner* than they can be obtained in the latter; and thus the activity of the gonads seems to be considerably dependent on temperature and the climatic conditions available.

Sometimes during the breeding season, geckoes may be seen fighting with each other, and it is believed that such fights are associated with sexual selection. Baini Prashad (1916) reports to have several times seen " a single female chased by three or even four males, and later found the males fighting amongst themselves for the possession of the female". Although this sort of explanation for fights may be true in some cases, it must be reiterated here that geckoes are much faithful to their own sites in the house, and thus a stranger's intrusion into the favourite preying-grounds of one individual is likely to be resented by it and so to lead on to warfare. Sexual selection cannot, at any rate, be invariably the cause of geckoes' fights.

### 16. *Sexual Dimorphism.*

As already pointed out by me elsewhere (Mahendra, 1935), the notion that there is disparity in the sizes or the degrees of activity of the two sexes in *Hemidactylus flaviviridis*, and that the male, therefore, "can be easily distinguished even from a distance" (Baini Prashad, 1916) is not right. An actual examination of more than three hundred specimens and careful observations on live individuals do not confirm such ideas. The size appears to depend not on sex, but almost entirely on age and on the amount of food obtained by the individual. The only reliable method, therefore, to determine the sex externally is to look for the femoral pores, which are absent in the female, and for the postanal bones and sacs (Noble, 1921; Smith, 1933, 1935). Besides these features, the male shows, in the breeding season, two swellings[18] on the ventral aspect of the base of the tail, separated by a slight longitudinal depression. The female has this area either flat or slightly concave.

### 17. *Courtship.*

Baini Prashad (1916) gives the following interesting description of courtship, from which my own observations differ considerably:

"This pair of lizards was seen on the wall of a bathroom. The female was sitting quietly on the wall, while the male was moving round the female in circles at a fairly rapid pace, and looked greatly excited. It would some-times stop, come near the female, nod its head, touch the female, and then

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[18] Described for the first time by me (Mahendra, 1935).

again resume going round the female; it went on like this for about ten minutes, when the male finally stopped by the side of the female, and lay parallel to it. The male now began to nod and touch the head and the body of the female oftener, even so much as slightly stroking it; it would sometimes put out its tongue and just lick the female. The female also now became responsive, and turned its head towards the male, thus the initial stages of courtship were completed."

I have witnessed two cases of courtship and copulation in this animal and noted them carefully, and my own observations are as follows: The male starts chasing the female, the latter going ahead quickly, stopping to allow the latter to come somewhat nearer and again running away from it. For some time the chase goes on. They both appear to make a low "*tak-tak-tak*" sound. From a distance of about 3–4 feet they lash their tails rather vigorously from side to side. On nearer approach, they may bite at each other's limbs and other parts of the body. After these initial overtures the actual act of copulation begins.

## 18. *Copulation.*

Recently, Noble and Bradley (1933) and Schmidt (1935) have drawn attention to the importance of accurate observations on the mating behaviour of lizards and have described this performance in several American species. According to the previous author, the courtship and mating of lizards is a very stereotyped performance, which has changed slowly in phylogeny; and a single type of this behaviour is usually found throughout a natural group of species and genera. It is necessary to study the Indian types also from this standpoint and to fill up the gaps in our knowledge in this important aspect of Biology.

In the house-gecko (H. *flaviviridis*), the act of copulation (Plate XVII) generally takes place on walls, and it lasts for 3–4 minutes or even longer. Dusk, early and late in the evening and even in the morning appear to be the most usual times, and the selection of the place, provided it is comparatively safe from noisy intrusions and is rather dark, does not seem to matter. The male climbs upon the female's back. It keeps firm hold of the female by gripping by its mouth at the latter's neck region and by pressing its right fore- and hind-feet (or, maybe left) on its back, the feet helping in adhesion by their subdigital lamellæ. It is possible that the sucker-like femoral pores and the two postanal pouches also aid in the process. The female lifts up the base of its tail and arches it in such a way that although the vent is held up off the wall, the tip of the tail touches it. The male now slides its tail under that of the female, and tilts its caudal region so as to make

its vent come to lie opposite that of the female. The two hemipenes of the male get everted, but whether one or both of them are inserted into the vent of the female, cannot be definitely asserted. However, it is generally believed (Smith, 1935) that in lizards "only one organ is inserted, but which one is immaterial, and depends upon the side the male happens to be at the time of copulation."

Even after separation, the male's copulatory organs remain everted for some time. It might be noted that the male and the female, on being slightly disturbed while mating, do not immediately separate from each other, but actually move off clinging together.

### 19. *Fertilisation of the Ova.*

The fusion of the spermatozoa with the mature ova appears to take place in the upper part of the oviduct; but at the time of mating the ova are not present in the oviducts, but are still within the ovaries. A female house-gecko was caught immediately after copulation and kept for about 12 hours, when it was dissected. It was found that there were no eggs in the oviducts, but the ovaries contained almost fully ripe ova, one ovum in each.

The *viability* of the spermatozoa of *Hemidactylus* has not so far been determined, but in the Sauropsida, as a rule, it is remarkably great. Lillie (1908), talking about fowls, says: "The period of life of the spermatozoa within the oviduct is considerable, as proved by the fact that hens may continue to lay fertile eggs for a period of at least three weeks after isolation from the cock. After the end of the third week the vitality of the spermatozoa is apparently reduced, as eggs laid during the fourth and fifth weeks may exhibit, at the most, abnormal cleavage, which soon ceases. Eggs laid forty days after isolation are certainly infertile, and do not develop (Lau and Barfurth)." Amongst reptiles, a case is on record of a female Night-Adder (*Causus rhombeatus*), which was "able to retain functional spermatozoa for at least five months, as four clutches of fertile eggs were obtained....without mating. It must be remembered that the snake was in captivity and that a similar course of events may not occur in a state of freedom" (Woodward, 1933).

### 20. *Intra-Uterine Development of the Ovum.*

The earlier stages of development in *Hemidactylus* are passed through in a special part (*uterus*) of the oviduct inside the body of the mother (Text-Fig. 1). The oviducts, which lie lateral to the ovaries and remain suspended by folds of peritoneum (*broad ligaments*), can be divided each into four parts: *viz.*, the funnel-shaped opening, the anterior tubular part, the middle part

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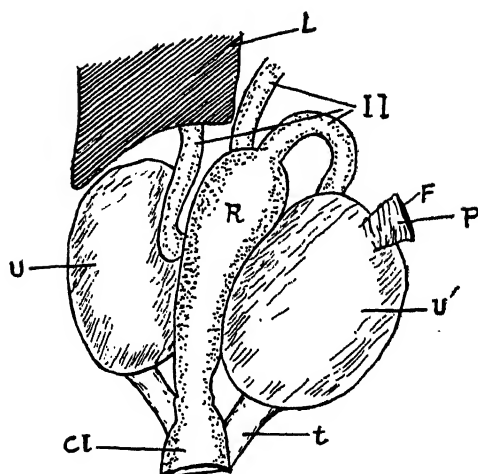
TEXT-FIG. 1.—Female Reproductive Organs of *Hemidactylus flaviviridis*, natural position. *Cl.*—Cloaca; *F.*—Funnel-shaped opening of oviduct; *P.*—First part of oviduct; *U, U´*.—Uteri with eggs developing inside; *Il.*—Ileum; *L.*—Liver; *t.*—Terminal part of oviduct, opening into the Cloaca. (Slightly more than $\times 2$ natural size.)

or *uterus*, and the last portion or *vagina*. The funnel is an extremely thin-walled opening, obliquely directed. The funnel of the right oviduct generally lies, in a full-grown female, about ·2 inches anterior to the ovary, while that of the left lies more or less at level with the ovary of its side. The funnel leads into the thin-walled anterior portion of the tube, which is arranged in the form of flat plaits. The *uterus* or the middle part is a short wide chamber with thicker walls than the rest of the oviduct and has marked longitudinal folds inside to allow for the expansion of this region in order to accommodate the mature egg, which comes to lie and to develop here. It is in this part that the earlier development of the embryo inside the egg takes place. The last portion of the oviduct leads by an aperture into the cloaca.

Each uterus usually contains one developing egg, but sometimes only one of the uteri has the egg inside, the other being empty. Although a great many gravid females were examined, the uteri were never found to contain more than one egg. Two eggs developing simultaneously, one in each uterus, seems to be the commonest condition.

Careful examination shows that in *Hemidactylus flaviviridis* there is no connection at all between the walls of the uterus and the developing egg that might be interpreted as "placental" in nature. The eggs simply lie and deveolp in the uterus, which only acts as a container for them. The egg on the right lies cephalad to that on the left, being placed just

behind the liver.   No marked difference in the amount of circulation in the uterine wall could be observed as compared to the empty condition.

Kerr (1919) describes three types of reptiles, in which we can make out three steps in the evolution of viviparity.   In the first type (*Anguis, Vipera, Coronella*), the egg is merely retained within the uterus, the shell still remains and there is no intimate relation between fœtal and maternal tissues.   In the second type (*Chalcides ocellatus*), the early rupture and eventual disappearance of the shell makes the fœtal and maternal tissues come into intimate relations with one another, both become highly vascular and there is an attempt at the formation of yolk-sac placenta.   In the third type (*C. tridactylus*), an allantoic placenta develops.   It is clear that *Hemidactylus flaviviridis* belongs to the first of these types, and it seems probable that all the members of the family Gekkonidæ will be found to belong to this very type.

How much time after copulation the fertilisation takes place, and how many days afterwards the oviposition occurs, I have not been able to determine quite definitely so far.   Baini Prashad (1916) records that in the case of a lizard (*H. flaviviridis*) he kept under observation, the eggs were laid "just about two months after copulation," and feels that the oviposition in this case was unduly delayed.   "Perhaps the delay in the laying of eggs," he adds, "in this particular case, was due to want of nourishment, as the animal did not take any food whatsoever all the time.   The eggs after being laid were covered by the mother with clay so as to be hidden from view" (p. 838).   My own observations in respect of time do not tally with Baini Prashad's.   I caught a copulating pair on the 14th April, 1935, and kept the two lizards in a fairly large box with lots of earth inside in order to note the date of oviposition.   For days together, I waited eagerly for the laying of the eggs, and ultimately in despair, I had the two removed from the box on the 8th May, 1935.   On looking carefully in the earth, however, I found two lizard eggs buried in it.   Thus *the oviposition had already occurred within 24 days of the copulation*, which differs remarkably from the time (2 months) observed by the previous author.

### 21.   The Egg and its Structure.

Generally the female lays *two* eggs, but less frequently it may lay even one, in a single batch.   The eggs (Plate XVI, Fig. 1) are white, spheroidal and brittle-shelled, and they are laid in some hidden crevice, hole or secluded retreat in the house.   In one case, I obtained them from within the drawer of my office table, where they lay beneath some papers ; in another, I found them behind my books in a book-shelf.   The mother apparently does not take the least care of them after oviposition and leaves them to hatch by

the natural warmth of the surroundings. The freshly-laid eggs have a more or less soft shell; but as they dry up, the shell becomes hard and highly fragile. With reference to the eggs of the family *Gekkonidæ*, Malcolm A. Smith (1935) says, "when first laid they are......covered with an adhesive glutinous substance which causes them to stick to any surface as well as to each other." I have not observed the presence of any such adhesive substance in the eggs of *Hemidactylus flaviviridis*, even when new laid, nor have I so far found the eggs stuck to each other, or to a substratum. The absence of the sticking substance in the eggs of this species might perhaps be accounted for by the fact that the eggs are laid inside crevices and holes in the walls, and that there is not much likelihood of ther slipping off and falling down. One might mention that in a generally tree-frequenting species (*H. mabouia*) of the same genus, the eggs "are soft and sticky when laid and thus adhere to the bark, in whose crevices or beneath which they are deposited" (Loveridge, 1920), and that in the genus *Gekko*, the eggs are deposited collectively and form shorter or longer strings (Das, Das, etc., 1931).[19]

The species investigated by me (*H. flaviviridis*) does not show the habit found in many other members of the family *Gekkonidæ*, of laying eggs collectively in the same batch. This, however, cannot at present be said of all the species of *Hemidactylus*. With reference to *H. mabouia* Mor., Loveridge (1923) reports that he found five eggs beneath an earthen pot, twenty beneath a pile of rotting palm-trees, and five beneath logs; and these findings create the suspicion that the members of this species are in the habit of laying eggs collectively at the same spot.

The shell in the eggs of *Hemidactylus* is both porous and calcareous in nature. The presence of calcium carbonate in it can be readily demonstrated

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[19] The note by Mookerjee and Das, "On the Breeding-habits of *Gecko verticillatus*" (*Curr. Sci.*, Dec. 1932, pp. 164–165), is nothing more than a repetition of some of the obesrvations originally made by B. K. Das and others (*Ind. Sci. Cong., Zool. Abstracts, 18th Annual Meeting*, 1931).—*Vide* editor's comment in *Curr. Sci.*, Feb. 1933, p. 252.

In a private communication to me, dated August 17, 1936, Dr. B. K. Das says: "Once or twice I have had the opportunity of witnessing the laying of the blood-sucker's (*Calotes versicolor*) eggs; they are glued to one another at that fresh stage, for a very short period (nearly half an hour), because the shell is quite soft and leathery and is coated with the adhesive secretion of the oviducal glands. On drying up a little, however, the eggs separate from each other. The partial and temporary adhesion of eggs in this Agamid lizard may perhaps be compared with the case of the tree-gecko, *Gekko gecko* (Linnæus), called *Gecko verticillatus* Laurenti formerly, and popularly known as the 'Thokkhak Lizard' in Bengal. That lacertilian lays hard-shelled, brittle eggs, which are very firmly glued to one another and often form clusters adhering to trees. In this connection, one might mention that the presence of adhesive secretion on the eggs of *Calotes* has not been recorded so far. Simkins and Asana (1930), Asana (1931) and Smith (1935) make no mention of it."

by treating it with dilute hydrochloric acid, which leads to effervescence on account of the escape of carbon dioxide, by adding ammonium oxalate solution to the filtrate, thereby producing a white precipitate of calcium oxalate, and by the flame test, which gives a brick-red colour, not persistent. Internally the shell is lined by a delicate membrane.

In size, the eggs of *H. flaviviridis* measure 12–13 mm. across the long diameter, and 10–11 across the short. On an average, they weigh about 900 mg. each. I had also had the occasion of collecting and observing the eggs of another species, *H. brooki*, and I found that these eggs were much smaller than those of *H. flaviviridis*, being only $7\frac{1}{2}$ mm. $\times$ $8\frac{1}{2}$ mm., or slightly more. Loveridge (1923) mentions the size of eggs for *H. brooki* as 11 mm. $\times$ 10 mm., which differs remarkably from my own observations, and I am unable to account for this discrepancy. Loveridge's observations concerned East African specimens, but that hardly accounts for such a large difference in the size of eggs. Loveridge (1920) also records that the eggs of *H. mabouia* measure 10 to 12 mm. in diameter.

Several times, eggs were obtained from the breeding-cage, which were deficient in the formation of the calcareous shell and showed at places a shrunken appearance. This was perhaps due to insufficient secretion of the calcareous matter by the walls of the oviduct probably owing to food deficiency, as it has always been a problem to me to feed the lizards adequately in captivity, and, more often than not, they have had to be kept semi-starved.

The eggs, fresh from the ovaries, are slightly heavier than water, and they generally sink to the bottom on being kept in a basin full of it. After laying, however, as time goes on, they become more and more light on account of the development of an air-space, which is relatively considerable in an older egg. During the last days of development, this air space may occupy even as much as one-third to one-half of the entire capacity of the egg, its size apparently depending on the relative drought of the atmosphere.

It is interesting to note that the eggs float in water always with the *same* surface pointing upwards, and can right themselves, if placed the other way up. If placed on a comparatively level piece of ground, they also behave similarly. Several eggs were marked with ink so as to point out the surface that remains directed upwards naturally, and dissection showed that the air space lay just below this surface. The eggs rotate to keep this surface upwards, because the other surface is much heavier, the developing embryo being situated just below the air space. The function of this peculiar device is to keep the proper orientation of the egg while the development is proceeding.

It is generally believed that the reptilian eggs increase in size after being laid (*e.g.*, Smith, 1935, p. 5). In the case of *H. flaviviridis*, however, no
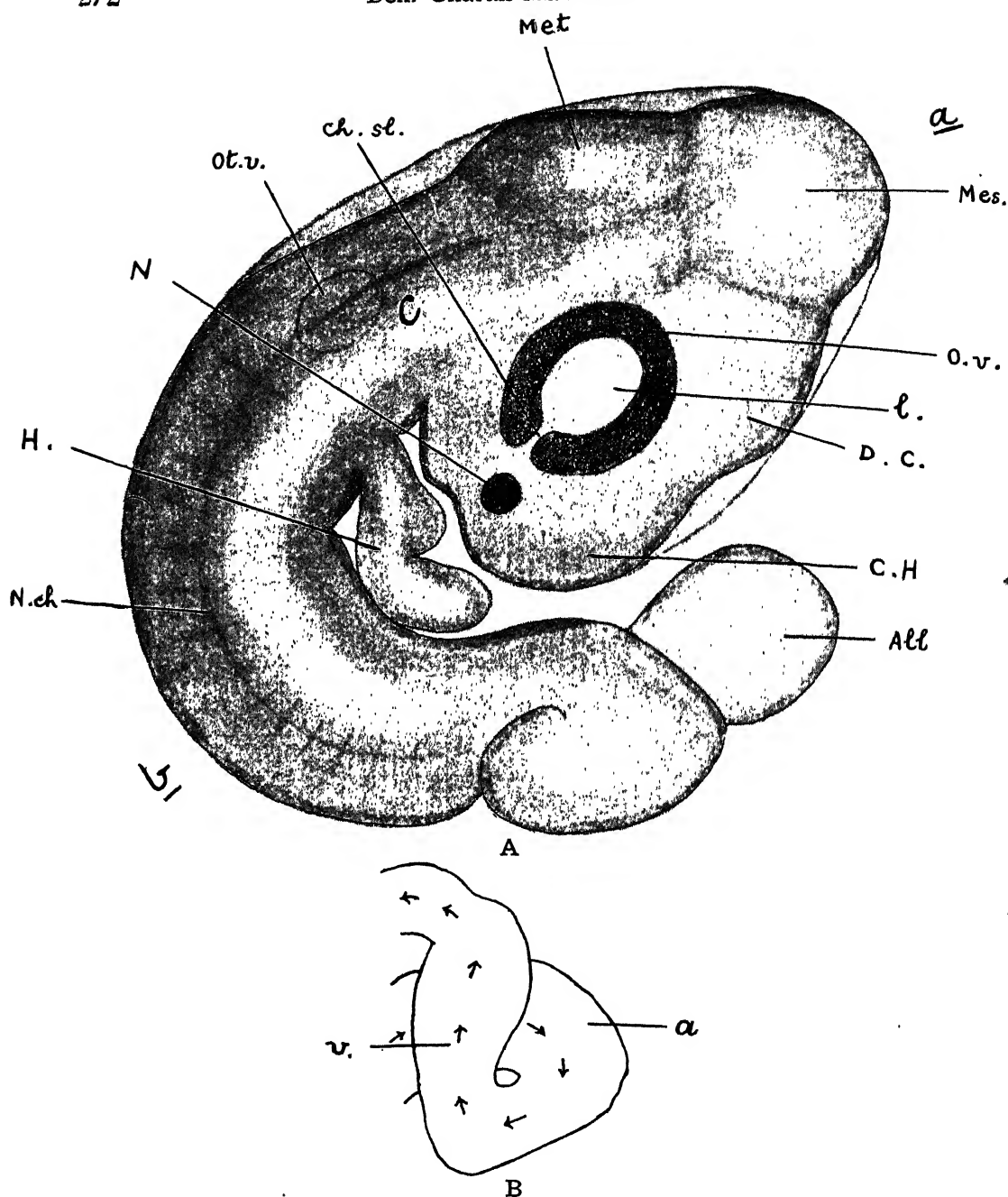
TEXT-FIG. 2.—(A)—Embryo of *Hemidactylus flaviviridis* in a newly laid egg. (B)—Its heart, as seen under microscope in the living condition. The arrows denote the course of circulation. (The outlines of the figures were drawn by the aid of an Abbe's camera lucida.) × 37.

*a.*—Atrial limb of the heart; *All.*—Allantois; *C.H.*—Cerebral hemisphere; *ch. sl.*—Choroid slit; *D.C.*—Diencephalon; *H.*—Heart; *l.*—Lens; *Mes.*—Mesencephalon; *Met.*—Metencephalon; *N.*—Nasal pit; *N. ch.*—Notochord; *O.v.*—Optic vesicle; *Ot.v.*—Otic vesicle; *v.*—Ventricular limb of the heart.

increase in size of the eggs could be perceived, and the weight diminished to some extent as development went on owing evidently to the increasing air space and the absorption of the yolk. The eggs incubate by the natural heat of the surroundings, and contrary to what is found in the fowls' and most other reptilian eggs, the presence of moisture around them is not a necessary condition of development. The albumen inside is dense white ; there is no chalaza, as in Birds' ; and even the new-laid egg contains a fairly advanced stage of the embryo.

### 22. *Embryo in the New-laid Egg.*

In a freshly laid egg, the embryo in its natural condition is curved upon itself, and generally measures, without straightening, approximately 3·5 mm. (Text-Fig. 2, *a* to *b*) ; its head being 2·1 mm. long (*i.e.*, from *a* to *c*). Some eggs show smaller embryos than this, the smallest that I have got being 2·5 mm. long (without straightening) and having a head 1·6 mm. in length. More rarely, even slightly bigger embryos might be found.

Microscopic examination of such embryos (Text-Fig. 2) shows that the anterior and the posterior limb-buds have not yet made their appearance, and that the heart is fairly well formed, being tubular in structure and bent upon itself. The circulation of the blood can be readily made out in a freshly opened egg, if the embryo is kept in the normal saline solution. The embryo continues to live in this solution for some time; and the pulsation of the heart and the course of circulation can be easily seen. The mesoblastic somites have differentiated almost all along the length of the body, especially after the otic vesicle. The brain shows the differentiation into telencephalon, diencephalon, mesencephalon and rhombencephalon. The otic vesicle is present as a round structure behind the head ; and the eyes appear in surface view to have a choroid slit. The allantois is a clear transparent bag attached to the posterior end, and the anterior part of the body of the embryo is enclosed in a large amniotic fold. Nasal pits can also be made out.

### 23. *Development after Laying.*

After laying, as already mentioned, the embryo inside the egg continues to develop of itself on account of the warmth of the surrounding atmosphere, the mother taking no care of it at all. The developing young one (Text-Fig. 3) becomes larger and larger, and it appears to sink down into the yolk, which becomes somewhat excavated to receive it. A considerable air space forms in the upper region of the egg, and serves not only to keep the egg properly orientated, but also to ventilate it. The limbs make their appearance, the tail develops in length, the allantois disappears from view, the
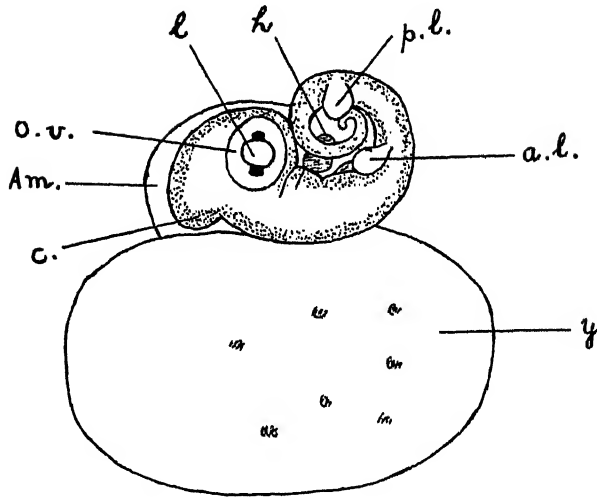
TEXT-FIG. 3.—Developing young one of *Hemidactylus flaviviridis.* (Fifteenth day after laying
of egg.)

*Am.*—Head fold of amnion; *a.l.*—Anterior limb buds; *c.*—Cerebellum; *h.*—Heart;
*l.*—Lens; *o.c.*—Optic vesicle; *p.l.*—Posterior limb buds; *y.*—Yolk.

granular scalation of the skin is formed, and many changes set in the
internal organs, so that in the final stages of intra-oval development, the
young becomes—to all intents and purposes—a miniature gecko lying coiled
upon itself, ready to hatch. It is remarkable that the embryo, even two
or three days before hatching, is so agile and vigorous that the liberation from
the shell and its membrane may lead to its running away. Once, while
engaged in collecting the highly advanced stage, I had the surprise of my
life as the embryo darted off on my opening the shell and had to be captured
about 6 feet away. Its yolk-sac, fairly conspicuous, hung to its belly, and
one would have thought that it was incapable of such a performance.

Before hatching, the embryo (Plate XVIII) lies coiled upon itself so that
its head is bowed down, due to cranial flexure, slightly on to one side of the
chest, overlapping the fore-limbs, its back is markedly curved, its tail is
doubly bent in the form of an "S", the distal part lying curved upon the
temporal region of the head, and the fore-feet overlie the chest, hidden by
the head, while the hind-legs are extended forwards on either side of the
tail. At times, the embryo undulates inside its membranous covering, and
hence the disposition of its parts, as described above, may be slightly
disturbed.

The rate of development appears to depend to a considerable extent on
the temperature of the environment, but on the whole it might be mentioned

that the incubation period in nature extends over $4\frac{1}{2}$ to 5 weeks from the time of laying.    As examples, I might cite the following two cases :

(1) *Eggs laid* : 4th May 1935.
    *Hatched* :    6th June 1935 (night).
    *Incubation period* : 34 days.
(2) *Eggs laid* : 2nd May 1935.
    *Hatched* :    3rd June 1935 (noon).
    *Incubation period* : 33 days.

In both these cases the eggs were laid in my cage, were properly marked, and were kept apart from others for the noting of the incubation period.

Baini Prashad (1916) records a case, in which eggs laid on the 8th. of May hatched on the 13th of June, "about 37 days after the eggs had been laid".

### 24.  Hatching, and the Young Lizard.

Malcolm A. Smith (1935) says, "For the rupture of the shell the embryo is provided with a sharp calcareous egg-tooth at the extreme tip of the snout.    This is shed shortly after birth. *In the Geckoes the tooth is double,*[20] but in all other lizards, so far as is known, it is single.    Annandale (1912) has suggested that, in some cases, the rupture of the shell is effected by means of the claws.    His view is supported by the knowledge that in some Chelonians rupture of the shell by the claws and not by the egg-tooth is definitely known to occur."    Baini Prashad (1916), with reference to *Hemidactylus flaviviridis*, however, notes that "no egg-tooth was to be seen on the head of the young ones."

Although I have examined several newly-hatched young ones, as well as ready-to-hatch embryos of *Hemidactylus flaviviridis*, I have not been able to find any trace of the egg-tooth, and I am, therefore, in a position to confirm Baini Prashad's observation (1916) about its absence in this lizard.    The breaking of the shell apparently takes place on account of the great pressure created by the struggling of the growing young one inside the egg and the extreme fragility of this structure.    Unlike the broken shells of the agamoid lizards, *Calotes jerdoni* (Venning, 1912) and *C. nigrilabris* (Annandale, 1912) which show "peculiar parallel slits and triangular flap" after the escape of the young, the eggs of *H. flaviviridis* are split open by a roughly round piece of the shell breaking apart and making an opening for the young gecko to pass through.

The newly hatched *Hemidactylus flaviviridis* (Plate XVI, Fig. 2) measures approximately 54 or 55 mm. from the tip of the snout to the end of the tail,

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[20] The italics are mine.—(B. C. M.)

the length from snout to vent being 25–26 mm., while the tail measures 28 or 29 mm. The size of such young ones, as mentioned by Baini Prashad (1916), is 58 mm., "the tail being 28 mm." The average length ascertained by me differs but slightly from his measurements, possibly due to individual variations.

The newly-hatched young ones of another species of *Hemidactylus* (*H. brooki*) that I had occasion to observe are much smaller than those of *H. flaviviridis*, being only 33–34 mm. from tip of snout to end of tail, the distance between snout and vent being 17 or 18 mm.

In appearance, the newly hatched gecko resembles the adult rather closely. Its colour pattern, however, is more pronounced, and there is a minute longitudinal slit at the navel where the yolk was attached to the body. This navel mark disappears after some time. The young gecko is quite active, but experiments show that it is not able to climb up vertical glass surfaces as most of the adults can. I have kept the newly-hatched young ones in large open glass troughs for two or three days, and they have not been able to escape. The first sloughing takes place soon after hatching, and for the first few days the young gecko has not been observed to prey upon its insect food.

### 25. *Summary.*

The present paper is the introductory part of a series of studies made on the habits, anatomy and life-history of the Indian house-gecko, *Hemidactylus flaviviridis* Rüppel. The more important points dealt with herein are as follows :

(1) The systematic position of this lizard is reviewed, and the generally recognised definition of the *Squamata* criticised in the light of the more recent anatomical work.

(2) The history of the institution of the genus *Hemidactylus* and the species *H. flaviviridis* is concisely dealt with.

(3) A résumé of our knowledge of fossil lacertilians and Gekkonids is given.

(4) A suitable cage devised for the keeping and rearing of geckoes has been described, and the method of incubating the eggs also dealt with.

(5) An account of its general habits, food and feeding, sloughing, fidelity to particular sites in the house, caudal autotomy, regeneration, hibernation, age, etc., is given.

(6) The breeding season is observed to commence generally in March and to continue for several months.

(7)  External differences between the two sexes are noted.  It is found that two swellings on the ventral aspect of the tail make their appearance in the male during the breeding season.

(8)  The method of courtship and copulation has been described.

(9)  Observations are made on the size and nature of eggs, their fertilisation, intra-uterine development, incubation, hatching and many other related questions.

### Post-Script.

After the present paper had been sent to press, Prof. C. R. Narayan Rao informed me that Mr. Y. Ramachandra Rao submitted a thesis on " The Lizards of the Madras Presidency " for his M.A. Degree in the Madras University in 1905.  On enquiry, I found out from the author that the thesis, which was "partly systematic and partly bionomical," was not published, but that it was later worked out into a series of popular articles, which appeared in the *Magazine of St. Joseph's College, Trichinopoly*, in 1915–17.  Through the kindness of Prof. P. T. Chandi of our College, I have been able to consult the necessary issues of that magazine.  Mr. Rao's observations, which are not very extensive and concern the species *Hemidactylus brooki, H. frenatus, H. leschenaultii* and *H. triedrus (H. flaviviridis* not being found in South India), do not differ from my own in any essential points.  I must, however, point out the following :—

(1)  *H. brooki.*—"This gecko seems to breed throughout the year in Southern India.  Two eggs.—more or less rounded in shape—are laid at a time, mostly in crevices in walls or in heaps of stones.  They hatch—of their own accord—in 34 to 42 days" (July 1915, p. 61).  My own observations, which concern specimens found at Agra, show that the eggs of this species are laid in July and August, and not throughout the year.

(2)  *H. leschenaultii.*—"This form probably breeds throughout the year" (Sept. 1915, p. 129).

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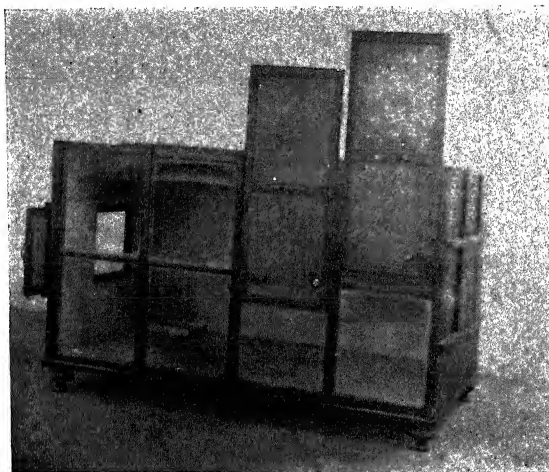
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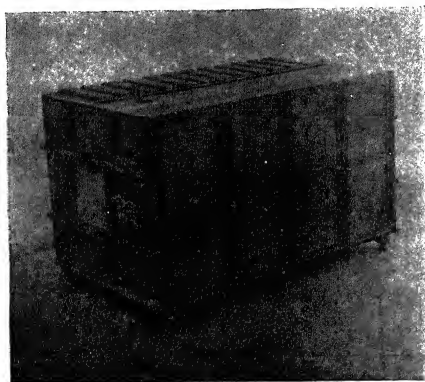


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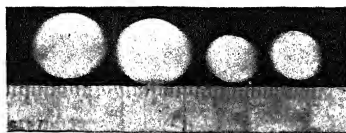
FIG. 1.



FIG. 2.



FIG. 3.

Mating posture of *Hemidactylus flaviviridis.*

Embryos shortly before hatching.



A    B    C

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## EXPLANATION OF PLATES.

### PLATE XIV.

FIG. A.—A view of the breeding-cage for geckoes. Two of the front doors have been entirely removed, the other two are shown slided up. The window in the side-wall (left) is open, and the porcelain dish for drinking-water can be seen inside.

FIG. B.—The cage, as it appears when fully closed and locked. On the top are seen the rows of drawer-shaped niches (closed), and the trap-door for throwing in the insects (this is open).

### PLATE XV.

FIG. A.—The top of the cage, showing the covers of the breeding-niches. Five of the niches are slid open. The cross-bars are for locking the whole series up. The trap-door is closed.

FIG. B.—The ceiling of the cage, as seen from below. The lizards can go into these niches, whenever they like to do so.

### PLATE XVI.

FIG. 1.—Eggs of *Hemidactylus flaviviridis* (large) and *H. brooki* (smaller), to show comparative sizes.

FIG. 2.—The newly-hatched young ones of *H. flaviviridis* (left) and *H. brooki* (right) to show comparative sizes.

FIG. 3.—A specimen of *H. flaviviridis,* sloughing.

### PLATE XVII.

Mating posture of *Hemidactylus flaviviridis.*

### PLATE XVIII.

The embryos of *Hemidactylus flaviviridis,* as they lie coiled inside the egg. Figs. A and B show the embryo, slightly disturbed.

# A GEOGRAPHICAL ANALYSIS OF THE LOWER INDUS BASIN (SIND).

BY PROF. MANECK B. PITHAWALA, B.A., B.Sc., L.C.P., F.G.S.,
*Research Certificate, University of London.*

## CHAPTER I.—PHYSIOGRAPHY.

### I. The Region as a Whole.

*Boundaries.*—The region, mainly characterised by the growth of the Indus delta, occupies the lower valley of the river. It covers 52,994 sq. miles including the Khairpur State. It is bounded on the west by the Kirthar Range (misnamed Hala), along with a chain of minor hill ranges as far as Cape Monze, and on the east delimited by the Rajputana Desert. The Arabian Sea forms its southern boundary, while to the north it extends upto the foot of the Suleiman Range and the extreme apex of the delta—a narrow neck of the Indus Valley, between the mountains on the right and the sand-hills on the left. (See Plates 1 and 16.)

Two of these boundaries—the northern and the eastern—are only political and not physiographic, as they are to be extended into the neighbouring States. It is expected that when the physiographic divisions of the rest of India are made, these boundaries will be definitely settled on physiographic lines.

*Distinguishing Features.*—The following are the outstanding features of the Lower Indus Basin :—

(1) The area includes the old valley of the Indus, which has reached its base-level of erosion and in which aggradation is more or less complete. It is in continuation of the *Khadar* alluvium of the Indus in the upper region.

(2) The rocks within the region are mainly Tertiary, thrown into anticlinal folds, which are being continually eroded by sub-aerial agencies.

(3) There is an extraordinarily large number of thermal springs, some of which show a temperature as high as 126° F. and evolve sulphuretted hydrogen gas. Although there are some extinct volcanic cones noticeable in Makran and Baluchistan, no volcanic eruption has taken place in the

region within historic times. The surrounding mountains being young and highly folded, are still in unsettled equilibrium and so earthquakes are not uncommon.

(4) The vagaries of the Indus River and its tributaries in the upper region (the Punjab) have also affected this area to a considerable extent. Due to these hydrographical changes, as also to the fact that a whole river, called the Hakra, has dried up, a large portion of the alluvial plain has been converted into a desert, entrenched with old river beds, which remain dry during the greater part of the year, due to the scanty precipitation in Sind. Drought and famine have been frequent in certain parts of it.

(5) Climatically, the region is said to be " between the two monsoons " —the S.W. from the Indian Ocean and the N.E. or "retreating" monsoon, deflected towards it by the Himalayan mountains,—and escapes the influence of both. The average annual rainfall is only 6 inches.

(6) But what is lost by the region during the two seasons is, however, regained for it by the Indus, the main artery of Sind, in the form of inundations, caused twice a year, by the spring and summer melting of the snows on the Himalayan heights and by rainfall during the monsoon season. Variations of diurnal and seasonal temperatures are also great.

(7) The growing and advancing delta is a characteristic feature, a large part of the existing deltaic lands being reclaimed during historic times. Small and large towns, which once stood on the numerous successive mouths of the Indus in highly prosperous olden times, are now completely thrown inland in a barren state and replaced by the present rock-bounded harbour of Karachi.

(8) Although there are no good mineral resources in the province of Sind, its chief asset is its rich alluvial soil, which requires little tillage or manuring, for yielding crops of grain as well as fodder throughout the year.

(9) Parts of the sandy desert are overspread with natron-producing lakes called *Dhands*, which are characteristic of the Thar Desert. Salt and sand are continuously blown in from the Rann of Cutch by the agency of wind, and there are rich deposits of common salt (NaCl) and other salts found buried under sand-hills.

(10) Rain in the Thar Parkar area is not altogether absent; on the contrary in years of cyclonic storms, there is excessive precipitation. The result is that the so-called desert land is, for the time being, turned into grassland, giving rise to herd life and migration of population in intermittent seasons.

(11)  Earthquakes and cyclones are not unknown :—

The Basin is very near the earthquake zone passing through the Northern Highlands.

In 962 A.D. the Indus River deserted Aror and even towns like Bahmana-
bad were destroyed.

1819—Extensive changes took place in the Rann of Cutch,[1] affecting
Sind.

From 1845 to 1861 not less than 7 earthquake shocks were recorded.[2]

15th October 1896.—Shahbandar to Khanjuand through Thar Parkar.

14th January 1903.—Thar Parkar and Shahjanbad District. Fissures in
Badin and Moghulbin Taluka ; eruption of warm water and muds of
12 hours' duration.  Geyser-like blow-holes left, 15–20 feet in diameter
and 8–10 feet deep.

May 1905.—Dead fish washed off Clifton.  A layer 5–15 feet thick and
several miles long.

Cyclones also occur at times :

(*e. g.*) (1)  13th May 1902.

(2)  13th June 1902.  Wind velocity estimated to be 100 miles per
hour.  Tide rose 7′ 2″ on 16th June 1902.

(3)  1903 Tidal wave.—Shahbandar Taluka.  A tidal wave rose near
the town of Sindree, situated where a branch of the Indus joins the Rann,
which was permanently  submerged on the occasion,  a number of small
cones, six or eight feet in height, burst up from the ground and continued,
for many days, to emit bubbles of air and mud from their summits.

*Scenery.*—The scenery of Western Sind is that of low undulating plains,
the relief being mainly dependent upon

(1) the folded structure of the rocks,

(2) the soft and jointed nature of the rocks,  with consequent rapid
weathering,

(3) the erosion due to wind-currents combined with high aridity and
scanty rainfall,

(4) low dips of strata.

The windward sides of the hills are generally eroded and steeply scarped,
while the leeward sides are smooth and gently sloping.  There are, here and
there, synclinal hills and anticlinal valleys. Detached hills with low dips
are common in the plains ; while massive wall-like cliffs and precipices are
found in the mountainous parts.  Along the coast-line and in the interior
of Eastern Sind there are transverse and longitudinal sand-hills, which are

characteristic of the Thar Desert. Most of the streams in Sind have their beds dry during the greater part of the year. The main artery of the Indus itself is as shifting as any other alluvial river, and as it is a highly aggrading stream in these parts, the main valley is nearly flat, having long before reached its base level of erosion. The hard rocks in it are covered over with river alluvium, which has been accumulating since the Pleistocene period.

*Origin of the Indus Plain.*—To understand the nature of this Indus basin, it is necessary to know its origin. Although the Indus has been considered to be an antecedent river, having existed long before the Himalayas come into being, the formation of the Indo-Gangetic depression is, without doubt, connected with the upheaval of these mountains during the Tertiary epoch. Resting upon the three or four primitive nuclei or fragments of an ancient land-mass, the land of Asia embraced the folded mountain belt from Asia Minor to the East Indies, across Persia, Tibet and China and grew, in the end, into the largest continent in the world.

The conception of the crust of the earth floating on the molten magma underneath is assumed by many geologists. In the gigantic process of building the continents by means of the drifting and fusing of ancient land-masses with the mountain chains, there are local depressions and isolations noticeable. Discussing the structure of the whole continent of Asia, Prof. J. W. Gregory asserts, " During the process of deformation of the earth, the great mass of Africa acted as the hinterland or back-land, which pressing northward against Southern Europe, crumpled it against the Northern forelands and that in Asia the direction was reversed, because the great mass which acted there as the driving hinterland, lay to the North and the great depression in the crust lay to the South. Accordingly, the dominant Asiatic movement was from north to south. We now know from the work of Mushketov, Klebelsberg, Wadia and others that the Asiatic direction was locally reversed opposite the mass of the Suleiman mountains and the Pamir, which acted as a hinterland between the two forelands of Arabia and the Indian Peninsula."[3]

*It is perhaps due to these opposing stresses working in the neighbourhood of our region that a trough came into being,* and it grew deeper and deeper on the southern flanks of the Himalayas, as they rose higher and higher and ultimately lay parallel with the range.

Similar events were happening in Africa and other parts of the world at the same time. The great meridional belt of ruptures which made the great Rift Valley of the Jordan, the Red Sea and the Nile basin, was due to the stresses between the northward movements to the west of it and the southward movements to the east of it.[4]

The Indo-Gangetic depression was supposed by some scientists to be "a trough-fault similar to the Great Rift Valley of Africa and probably co-eval with the breaking up of Gondwanaland."[5]

From a number of geodetic observations of the amount of deflections of the plumb-line at and near the foot of the Himalayas at different distances, *viz.*, Kurseong, Siliguri, Jalpaiguri (25 miles), Birond, Nimkar (112 miles), and Dehra Dun, Kaliana (56 miles), Col. Sir S. G. Burrard, a former Surveyor-General of India, concluded that there was a rapid decrease in the deflections as one passed from the mountains to the plains, the reason being that "the attraction of the Himalayas was being counterbalanced by an attraction in the opposite direction and that an invisible chain of excessive density parallel with the Himalayas is underlying the plains of Northern India.[5] Even the location of these hidden chain of rocks was suggested by Burrard to be some 150 miles distant from the foot of the mountains. Thus he deduced the theory that the Indus plain must be at first a "Sunken crack or fissure on its two sides."[5]

But geologists, such as Fisher, Suess and Oldham, have not supported Burrard's hypothesis and suggested that the Indo-Gangetic depression is "a foredeep between the wave front of the Himalayan system of folding and the horst of Gondwanaland produced by the elevation of the mountain range with concomitant sinking, partly due to subsequent overspreading of the submontane tracts."[6]

The present view now generally accepted is that the Indo-Gangetic depression is "a broad basin, shallow on the outer side and sloping gently inwards towards the Himalayas, from which it is separated by a steep wall resulting from the series of reversed faults which separate the older geological systems from the younger."[7]

*Geological History.*—During the greater part of the vast cycle of geological time, Sind lay submerged under the Tethys Sea. Its land history is, therefore, comparatively brief—and yet the history as written by nature on its rocks, is fascinating. For its birth, it has mainly depended upon the upheaval of the extra-Peninsular mountains, the Himalayas. How these stupendous mountains rose out of the ancient sea, and how they brought into being the two flanks, the Burmese Yomas in the east and Suleimans and the Kirthars in the west, is a marvellous story. Incidentally the Indo-Gangetic basin came into being, as has been stated above.

Even before this stage of Himalayan upheaval, the earth movements, which took place in Peninsular India during the Cretaceous age, caused a bulge in the surface of Sind and there came on this surface the Cretaceous

rocks in the Laki Range, the most ancient geological formation yet met with in this province. This was Sind's first appearance on the earth.

This exposure of the Cretaceous in the Laki Range is due to a strike fault running throughout its length, caused by the stress of folding from west to east with an upthrown edge on the west. The Hippuritic limestone (equivalent probably to the Turonian) at the base of the Barrah hill, about 10 miles S.W. of Amri, is, therefore, the oldest rock exposed in Sind. It is about this time that there was also the deposition of the *Cardita beaumonti* beds and the dark sandstones in the Cretaceous sea.

Then there was the memorable volcanic (fissure) eruption of the Deccan trap lavas in the Peninsula and Sind had a small share of it in the form of a 40–90 feet thick bed of basaltic trap, on top of the Cretaceous rocks in some parts of the Laki Range. (See Plate 12.)

The land, thus formed like an island in the Tethys Sea, remained dry for a long time after the lava eruption, during which period there were laid over it quite extensive deposits of Ranikot beds by the streams, which flowed over it. Coincident with an upheaval in the Himalayan region the dry conditions persisted till the sea overspread the region again, and there were formed more Ranikot beds containing coloured clays and some lignite, probably buried in a swamp or bay not far from the coast.

The land was again largely submerged in the Kirthar (Eocene) sea, which lay between the Aravallis and the western mountains, and large deposits of limestone with soft and shaly beds were laid down. These contain a rich fauna of corals, echinoderms and molluscs. Lateral compression caused an upheaval and folded the rocks into anticlines and synclines.

Another continental period followed and there were temporary land conditions, now noticeable in the various ferruginous beds, commonly known in Sind as the Nari beds, formed in a shallow sea and in valleys between the Kirthar limestone bridges, by the influence of rivers.

One more subsidence in the Miocene (Gaj) age gave birth to the well-known Gaj fossiliferous limestone, so well distributed in the Kohistan area and largely used as building material. These also contain fossil corals, echinoderms and molluscs.

The last phase was fluviatile, marked by the Manchar formation of *Siwalik* age. This was the age of mammals.

The Sind gulf was then replaced by valley streams, which completed the work of filling in many a bay and lake, till ultimately the sea was completely withdrawn, leaving the central valley for the Indus River to flow into, so that by the middle of the Pleistocene period the outlines of the geography

of Sind had come into being.  It only remained for the Indus to bring its alluvium and drop it into the valley with the detritus from the Himalayan heights.  This gave a finishing touch to its physical features and shaped its topography.  As the Indus delta went on growing southwards, and the level of the Indus plain was reduced gradually, the river changed its course now and then, swinging from east to west and west to east.  Even to-day the process of lateral compression and mountain formation in the western highlands is not quite completed, the channels and mouths of the main artery of the land are not settled and the work of alluviation has not quite come to an end.  (See Geological Map, Plate 2.)

*Summary of Geological Formations occurring in Western Sind.*[8]

| Groups | Subdivisions | Approximate Thickness (feet) | Probable Geological age | Remarks |
|---|---|---|---|---|
| 9. Alluvium, etc. | .. | ? | Post-Tertiary | .. |
| 8. Manchar .. | Upper | 5,000 | Pliocene | Unfossiliferous representative of the fossiliferous Siwalik group |
|  | Lower | 3,000 to 5,000 | Lower Pliocene and Middle Miocene |  |
| 7. Gaj .. | .. | 1,000 to 1,500 | Miocene | Highly fossiliferous marine : no *Nummulites* |
| 6. Nari .. | Upper | 4,000 to 6,000 | Lower Miocene | Unfossiliferous |
|  | Lower | 100 to 1,500 | Upper Oligocene | Fossiliferous : Upper limestone with *Nummulites* |
| 5. Kirthar .. | .. | 500 to 3,000 | Upper Eocene | Nummulitic limestone |
| 4. Laki .. | .. | 6,000 | Middle Eocene | The lower beds unfossiliferous. Base not determined |
| 3. Ranikot .. | .. | 2,000 | Lower Eocene | Fossiliferous, *Nummulites* common |
| 2. Trap .. | .. | 40 to 90 | Lower Eocene or Upper Cretaceous | Representative of the Deccan and Malwa trap |
| 1. Cretaceous .. | (*a*) *Cardita beaumonti* beds | 350 to 450 | Upper Cretaceous or intermediate between Eocene and Cretaceous | .. |
|  | (*b*) Sandstones | 700 | Cretaceous | .. |
|  | (*c*) Limestones with *Hippurites* | 320 | .. | Base not exposed |

*Nature and Evolution of the Coast-line.*—The coast of Sind forms part of the plain of marine denudation with the sea hardly a few fathoms deep.

The sea face itself is determined by marine currents and not by any great deposit of sediment. The southwest corner of Sind, with the projection of Cape Monze forming part of the Kirthar Range, is the result of the extra-Peninsular crustal movements, lateral compressions and foldings, followed by the erosion of the coast by the Arabian Sea. It consists of limestone and sandstone rocks and wherever the sea has encroached upon the land as a result of erosion, small inlets and bays are formed. On the whole, the coast-line is unbroken and has not undergone subsidence. On the other hand, there are numerous evidences of upheaval on every side (*e.g.*) the presence of oyster banks now several feet above sea-level and of coral beds far inland (*e.g.*) at Mangho Pir. Near Manora and Karachi the work of sea erosion is most active, resulting in the formation of the natural harbour of Keamari (see Plate 12) and an excellent beach stretching for miles from Clifton. The condition of the oyster rocks and the formation of the backwaters of China creek point to the havoc wrought on land by sea waves. At Clifton and Gizri there is an increase of foreshore due to æolian deposits. Further eastwards the mouth of the Malir as also the numerous and changing mouths of the Indus show that the detrius brought by them rapidly change their size, nature and position. The coast-line in front of the Indus outlets is thus greatly changeable owing to the continuous growth of the delta, sand-bars, and deltaic lakes. A sandy but shifting beach of shoals, sand-hills, or *burkhans*, and mangrove swamps are prominent on the Sind Coast. On the side of Cutch there are distinct signs of a slightly upheaved shore touching the Rann towards the east, the Koree being the largest creek on this side. The coast being low, the tide-waters penetrate far inland and have formed a large marshy flood plain.

*Physiographical Divisions of Sind into Provinces and Sections.*—The area can be divided and subdivided into natural physical units as under :—

| Division | Province | Section |
|---|---|---|
| 1. Extra-Peninsular Mountains .. | I.  Western Highlands | (A) Kirthar Mountains<br>(B) Kohistan Section |
| 2. Indo-Gangetic Plain    .. | II.  Lower Indus Valley | (A) Western Valley Section<br>(B) Eastern Valley Section<br>(C) Deltaic Area |
| ,,      ,, | III.  Desert Province | (A) The *Pat*<br>(B) The *Thar* |

*Method of Division.*—The method employed is that adopted by the Association of American Geographers for the physiographic divisions of the

United States of America. In preparing the map of the Lower Indus Basin its physiographic history has been considered, *viz.*, the original structure of the land-forms, the process of land erosion by subaerial agencies destroying this structure and the recent stage of erosion or deposition of material thus eroded. The outstanding characteristics of the divisions depend upon these factors and the value of each unit is based on its homogeneity. (See Sections, Plate 14.)

*Need of Physiographic Divisions.*—The boundaries of these units are fixed with regard to their utility from the points of view of water-supply, economic resources, including agricultural products, industrial possibilities, population problem, etc.

*Sections Distinguished : Province (I).*—(A) This consists of folded strata, containing hard and soft rocks of sedimentary origin, deeply ravined and fissured here and there. There is little soil and no vegetation, due to the scanty rainfall, in spite of the altitude reached, over 6,000 feet.

(B) These are lower ranges composed of monoclinal, folds with undulatory plains in between. There is considerable subaerial denudation because of more rainfall here than in the Kirthar mountain area, nearness to the sea and humidity of the air. The soil is cultivable in the valleys and supports more vegetation. One of the hill-ranges, *viz.*, the Laki, contains pre-Tertiary rocks and there is also a large number of thermal springs located chiefly between the latitudes 24° N. and 26° N.

*Province (II).* (A), (B) *and* (C).—These include valley-plains, chiefly overlain with alluvium, both old and new, trenched with river-channels in some places and overridden by raised beds in others. A few isolated, low limestone hills are the only relieving feature in the plains which are otherwise quite level. The soil is rich in salts and in minerals, derived from the silt and debris, borne down by the river from the mountain heights.

The Western Valley Section (A) is distinguished from (B) the Eastern Valley Section, by the presence in it of (i) old alluvium and (ii) seasonal springs flowing down from the Kirthar mountain into the Western Nara and the Manchar lake.

(C) Deltaic Area—Largely uncultivable land consisting of mangrove swamps, *burkhans*, mud banks, shoals, sand-bars and flood plain. The chief characteristic of the region is the changing outlets of the Indus, which act as the inlets of the sea.

*Province (III). The Desert Province.*—This is " a regular sea of sands," of aggraded desert plains overlain with sand-hills. It is subdivided into (A) The *Pat.* This is the northern section of the desert consisting of clay

or silt covered with longitudinal 'bhits' or sand-hills connected by transverse ridges. There are also numerous ' Dhands ' or salt lakes.

(B) The *Thar*. This section is more full of high sandhills with a definite N.E.-S.W. orientation, though the rainfall in this area is somewhat greater.

The whole of this Desert Province is distinct from the extra-Peninsula, the Peninsula, or the Indus plain Provinces. But it possesses the characteristics of all the three, having rocks belonging to the extra-Peninsula, while their structure is that of the Peninsula and the stage of erosion is that of the Plains.

## II. Province (I): Western Highlands.

*Correlation.*—This province of the Western Highlands really forms part of the chains of extra-Peninsular mountains including the Suleiman and Hala ranges, and is capable of extension towards the north as well as the west. Its limits on these two sides is left undefined, until the work of designating the physiographic divisions of the surrounding lands and tracing their boundaries is completed.

*Peculiarities of the Rocks.*—The Tertiary rocks of Sind are in general similar to the Tertiaries of Burma, Assam and other parts of India.

(A) *The Kirthar Mountains*.

*General and Structural Features.*—The Kirthar mountains have a high relief (4,000 to 5,000 feet above the sea-level) with transverse torrents running down the eastern flank into the Indus Valley. They are deeply ravined and fissured and mainly consist of folded strata, weak as well as strong.

They run north and south like a crescent turned towards the low lands and extend from the northwestern extremity of Sind southeastwards to a little below the latitude 26° N. The maximum height is 6,877 feet above sea-level at Kutta-jo-Kabar (Dog's tomb) ; the southern end does not exceed 3,500 feet. It has a simple mountain structure of the regular anticlinal type, with the arches steepest towards the north and the west and gently dipping towards the south and the valley of the Indus.

The rocks exposed on the western flanks of the Range are Nummulitic limestones of the Kirthar (Eocene) series, while shales and soft sandstones are found between the ridges.

The whole range presents an arched or dome-shaped whale-back appearance, while its geology is singularly simple : " Many of the chains are perfect geological diagrams and from the absence of vegetation and clearness of the atmosphere, the outcrops of formations, such as the Nummulitic and Miocene limestones, may frequently be traced for many miles on the hill sides with absolute certainty from a distance."[9]

*Possibilities of hill-stations.*—There are two table-lands suitable for hill-stations on the Ridge, viz., (1) Dhar Yaro plateau, 6,000 feet high and exposed to high winds and having nearly a thousand acres of cultivable land. It has a mean summer temperature of 81° F. only and a rainfall of about 6 inches. Its ground is cut up by watercourses running down to the east into a deep and long ravine. The soil is yellowish red marl, washed from the heights, while the rock is red sand-stone interbedded with Nummulitic limestone. The well-known Kutta-jo-Kabar (Dog's tomb) is a junction of the eastern spur of Dhar Yaro with the main range of the Kirthar. It has other hills 300 to 700 feet high on its borders, so that the plateau is protected from all sides.[10] (2) Danna Towers, a plateau 4,500 feet high, situated on the second middle ridge, 50 miles S.W. of Mehar. The ascent is irregular and steep.

The southern Kirthars run in the N.W.W. and S.S.E. direction with a gentle slope into Kohistan.

*Passes and Drainage.*—There are transverse lines of drainage in the Range, which serve the double purpose of pathways through the frontier from the valley to the Iran plateau (*e.g.*) the Mula, Mushkot and Bolan passes and of flood torrents down the slopes called " nais," depositing a large quantity of boulders, pebbles, etc., along the hill-slopes. There are, also, a number of minor notches in the mountain, such as, Gazi Luk, Bakhar, Pinri, Harbab, Kamalune, Shakloina, Zamin, Phusi, Peei, Rohel, Garre, Musefiri, Kutta and Daimang.

*Nais.*—Among the important mountain streams issuing from the ridges and falling into the Indus plain are : (1) the Gaj *nai*, flowing through the Kamalune Pass and (2) the Nari *nai*, joining the former at a later stage. Other hill-torrents, which are either lost in the sandy plain below or, being temporarily lost, flow through the Western Nara into the Manchar lake every flood season are, the Sain, Kenji, Mogio, Trappen, Sita, Mazarani, Sahar Radha, Burri, Sulari, Khurbi and Maki *Nais*. Some of these *Nais* are so powerful during the season (June to August) that they destroy fields and villages several miles away.

Near these streams, the hills are surfaced with gravel, while along their foot are heavier boulders, pebbles, etc. " These extensive gravel slopes are quite characteristic of climates like that of Sind with a low rainfall, because in such tracts, rock detritus accumulates along the bases of hills more quickly than it can be carried away by the streams. The rainfall is sufficient to wash down the disintegrated fragments from the steeper slopes but not to carry them forward where the fall is more gradual."[11]

*Valley forms.*—As the mountains are of recent origin and as the nature of rocks varies, there are different types of valleys produced. " There is here ample evidence of local disturbances in the alterations of levels, extensive valley plains, occupying rock-bound basins and compressions of rock masses." Where the rocks are hard limestones, there are narrow and fissure-like gorges, steep V-shaped valley sides, and rapid streams. But wherever they are soft (*e.g.*) shales or sandstones, the valleys are " broad, open, smooth below and filled up with stream deposits or gullies."[12]

*Instability of the land.*—These mountains of comparatively recent growth are yet unsettled and the region falls within the seismic zone of the earth. Now and again, there are tremors and quakes, as results of fractures, fissures or subsidence of rocks. This instability may also be due to the growing delta of the Indus and the fault lines, recently discovered under the bed of the Arabian Sea in the neighbourhood.

*(B)  Kohistan Section.*

*Delimitation.*—This section covers all the lower ridges of hills and the undulating plains of rapidly weathering rocks, east and southeast of the Kirthar mountain, and extending as far as the sea coast in the south. The Indus bed lies flat against the higher levels of its right bank and cannot make any further advance against them. The hills constituting the ridges are named after some prominent peak or pass. There is an abundance of hot water springs.

*Topography.*—Low, parallel or sub-parallel ridges with broad undulating plains between them are the prominent features, indicating a lateral compression of the rocks acting west and east. The topography of this section is determined by the folded sedimentary rocks of the Tertiary system, disturbed by a vertical dislocation in the Laki Range and modified by the denudation by subaerial agencies to a great extent. The marine limestones, covered by soft clays and conglomerates yield to the action of wind and rain, resulting in the characteristic undulating plains topography. There are a number of lateral ridges, hundreds of feet in height, pushing into the plains and becoming conspicuous by means of their numerous spurs and peaks lying in the midst of deep and wide valleys.

*Chief Ranges*: (1)  *Laki Range.*—It extends north-south from Bhagothoro to Thano Bula Khan (height 2,202 feet).

(2)  *The Kambhu.*—15 miles long, in continuation of the Kirthar mountain but only 2,340 feet high.

(3)  *The Badhra.*—Nearly 30 miles long, north to south a simple anticlinal roll of Nummulitic limestone with its axis continuing southwest and

joining the Kirthar mountain in the south by a cross ridge (height 2,436 feet).

(4) *The Bhit.*—20 miles long and 2,790 feet high. West of Badhra; it is almost flat-topped, " a great anticlinal saddle of Kirthar limestone".

(5) *The Bidur.*—The eastern watershed of the Habb.

(6) *The Dunbar.*—15 miles long and 2,200 feet high, lies between the Bidur and the Kirthar Range.

*Structure of the Hill Ranges.*—Generally speaking, the anticlinals are steeper on the eastern side, and they " frequently consist of a double anti-clinal fold with a small synclinal between. Faults and dislocations are of rare occurrence and those which occur are frequently parallel to the axes of the hill ranges."[13]

*Importance of the Laki Range and its History.*—This is the most interesting of all the Kohistan hill ranges. The Vira plain lies to the east of it, while a broad intervening valley opens out the road from Karachi to Sehvan. It is a steep anticlinal fold, faulted across with its upthrow towards the west and with prominent escarpments. A considerable number of the upper and lower Tertiary rocks is exposed in it, thus becoming a regular " Museum of field geology". It is the only locality in Sind where there are Cretaceous rocks exposed. A fissure eruption, contemporaneous with the lava flows of the Deccan, has left its mark in a bed of basalt 40 to 90 feet thick but now highly decomposed. Between this volcanic rock and the Ranikot beds there is a break, there being a layer of fluviatile deposits of variegated shales and sandstones especially in the lower beds. The presence of oyster beds in certain places indicate local marine incursions in later geological times. Actually within the Ranikot beds there are layers of lignite, apparently showing marks of swampy areas, into which the vegetation grew and got subsequently buried. Near by, there is a layer of ironstone and ferruginous limestone and also laterite. As the Eocene sea receded at one time and attacked the land afterwards, the Nummulitic limestones were gradually deposited. Once again on the land becoming dry, the river and rocks of ironstone, soft brown sandstones, etc., of the Nari group were formed. The Miocene times again saw the marine incursions for a while, until at last there was the dawn of the Siwalik age with its mammalian fauna.

*Other Features.*—The whole range, though simple in structure, is much folded and is itself composed of several parallel ridges with valleys of varying breadths lying between them.

East of the range, there are only a few broken hills lying in a gentle slope reaching the meanders of the Indus. There are a few passes, or notches,

in it, *viz.*, Girran, Hoshian, Hala and Gagar.  Thane Bula Khan, about 700 feet high, would make a good sanatorium.

All the newer rocks belonging to the Nari, Gaj and Manchar series, *viz.*, sandstones, conglomerates, etc., being soft, lie denuded in valleys and plains, while the outcrops of compact and hard Miocene limestones do not suffer from extensive weathering and are conspicuous in many a detached hill in the south and southwest.

*Mol and Myher Plateaus.*—The undulatory character of the Kohistan area is absent in two masses of rock, called (1) the Mol plateau and (2) the Myher plateau, both lying in the northwest of Kohistan and to the east of the Habb river.  They are chiefly composed of soft Manchar rocks, which form a gentle synclinal or almost horizontal table-land.

But elsewhere the plateaux break up into the Gaj, anticlinals again predominating, as in the hills at Mangho Pir, Cape Monze, etc., in the north and northwest of Karachi.

*Drainage.*—(1)  *The Habb River.*  This is the only perennial stream in the region.  Its headwaters are in the Pabb Range beyond the limits of our region, but its main stream forms a rough continuation of the axes of the Kirthar Range and the western boundary of Sind.  An old but dilapidated *bund*, called Murad Khan's Bund, lies across it.

(2)  *The Baran.*—Next in importance is the Baran stream, rising near Tako Baran in the Kirthar Range.  It traverses the valley west of the Laki Range, where it receives the waters of the Nais, and later on cutting through it runs eastwards right through Kohistan into the Indus River, a few miles from the Bolari Railway Station.

(3)  *The Malir.*—This is a seasonal stream.  It joins the Khadeji at a later stage but lies dry for the greater part of the year. After heavy rainfall only, it flows into the Gizri creek near Karachi.  There is, however, an immense quantity of subterranean water underneath the sandy bed of the Malir, which supplies a number of wells and galleries along its right bank— the only source of water-supply of this locality.  At some distance from the Dumlotte gorge upstream, there is the confluence of the Malir with the Khadeji, which has more or less a perennial flow of water with a small waterfall also.

Among other minor streams of a similar nature are : the Lyari flowing into the Keamari harbour, the Mohan or Rani rising from east of the Laki Range, the Saun, the Chorlo, the Nie Naegh and the Angyi, all flowing into the Indus or the Arabian Sea, if not lost in the sandy tracts along their courses.

*Thermal Springs.*—No faults have been traced in these localities but it is obvious that water percolating through the folded and fissured strata of the anticlines penetrates to a depth of thousands of feet and gets heated in the interior. Release of pressure and the original head bring the hot water, charged with sulphurous gases, upto the surface again in the form of hot springs.[18] The most important are shown on the map, Plate 4.

The Mangho Pir spring is the hottest in Sind its usual temperature being 126° F., with a discharge of about 180,000 gallons a day. Other springs have their temperature ranging from 80° F. to 120° F.

*Sources of Water.*—That there is abundant supply of water from surface as well as deep-seated springs even at points hundreds of feet above the sea-level, has been proved both at Dumlotte and other places in the Kohistan region, the natural dip of rocks being also favourable (*i.e.*) towards the Malir valley. " Many of these (springs) are used up in irrigation and a still greater number after flowing from one to ten miles disappear in the sand or flow off into cavities of the limestone formation, through which they pass to appear again, doubtless in places at a lower level when faults bring the water to the surface."[15] There are good chances for artesian wells also in the Malir valley.

### III. Province (II) : Lower Indus Valley.

*The Province as a Whole.*—This valley presents a typical example of aggradation by the Indus throughout the post-Tertiary times. On either side of the river, there are long stretches of land, 2 to 12 miles wide, which are well watered, richly silted and cultivable.

This province is the most precious part of Sind and produces its main agricultural wealth. For this reason, a study of it is desirable from the points of view of :—

    (1)  Ground contours,
    (2)  Subsoil water-level contours (hydro-isobaths),
    (3)  Soil indications.

(1) *Ground Contours.*—The accompanying map of ground contours (see Plate 5) shows that the fall of the country is only about 180 feet, (from 200 feet contour in the northwest to 20 feet in the southeast corner) for a distance of about 250 miles (*i.e.*) nearly 8¾ inches per mile only.

The contours in the northern tracts run almost N.W.-S.E., those in the middle nearly E.-W. and across the river bed, while those in the south almost N.E.-S.W.

It is also easy to understand that the bed of the Indus is itself higher in level than the surrounding country.

The map shows breaks in the contours of areas too high for the Barrage to command.

There are practically no rocky outcrops or eminences in this valley.

Such a plain is ideal for cutting canals in any direction.

(2) *Subsoil Water-level Contours*.—Two maps showing the hydro-isobaths of the two main seasons, October (after the rains) and April (before the rains), have been prepared. It is a characteristic of the province that the subsoil water-level rises at the time of every inundation. On the right bank, especially a high subsoil water-table exists, varying from 3 feet to 13 feet below the surface. On the left bank the conditions are slightly better.

Under the old inundation canals system, as the inundation ceased to flow at the end of September and the beginning of October, the subsoil water-level had enough time, nearly 8 months, to recover before the next season ; but now under the perennial system of the Sukkur Barrage the drainage capacity of the soil has been greatly affected, and there is " a persistent upward trend in subsoil water-level " according to the general principle that the flow of water through subsoil is from areas in which the level is high to areas in which it is low. The average rise is 9 feet annually. As the whole area gets sufficiently saturated by irrigation water, the effect of additional rain-water during the season has little effect on the subsoil water-table.

October readings (see Plate 6).—These show that the water-level contour below the surface varies from 4 to 8 feet near the bed of the river to about 12 feet near the frontier on the right bank ; while the level is considerably below the surface even in the neighbourhood of the river banks on the left side, *viz.*, 16 to 24 feet. In the Khairpur State, however, the level is very high, *viz.*, 4 to 8 feet only, due to the passage of the large Rohri canal.

April readings (see Plate 7).—The contours on the right bank vary from 8 to 12 feet near the river bed to nearly 24 feet towards the N.W. frontier. On the left bank the levels vary from 12 to 16 feet near the Eastern Nara valley. In the Khairpur State it goes down to 8 to 12 feet only.

On comparing the April hydro-isobaths map with the October one we find that though there is an average drop of about 4 feet in April, the water-table is generally only about 8 feet below the ground level. This situation is on the left bank, while in the Khairpur State and also in some parts to the south there is a general tendency for the subsoil water to rise in October after the rains.

Outside the Barrage Zone, depth of the water-table varies from 60 feet in the Kohistan region to 300 feet in the Desert region.

*Utility of these Maps.*—The above information is a guide to the solution of the problem of seepage and water-logging in Sind. Contour plans of subsoil water have been prepared by the Development and Research Division since 1930, and for the months of (1) April when the level is the lowest before the Khariff season begins, and of (2) October when the effect of the monsoon irrigation on the land is clearly marked. Formerly, observations were taken of the rise and fall of water-level in existing wells in some parts of Sind twice a year. The more systematic readings, obtained by the Public Works Department in recent years, have enabled them to keep track of rises and falls of the subsoil water-table and to suggest plans for the prevention of water-logging in certain localities. It has been noticed that the area suffering from water-logging in Sind is only confined to the neighbourhood of canals due to seepage through sand-beds and banks, that it is very small compared to the whole area commanded by the Barrage and that this kind of seepage is getting reduced year by year due to the sides of the canals being gradually, though unevenly, sealed up by silt deposits. Such deposits have, however, been found to be fewer on the left bank area than on the right bank.

It is surmised that seepage and water-logging after the Lloyd Barrage are caused also by a buried ridge or up warp extending from Kohistan through Sukkur to the Suleiman mountains and indicated by gravity, data, which were obtained by the Survey of India (*vide* Geodetic Report, Vol. VIII, Chart 11). It might be proving to be an obstacle to the subsoil flow of water, thus causing a rise in the table.

(3) *Soil Indications.*—In a province, dominated by such a powerful aggrading river as the Indus, the soil is largely alluvial and sand is likely to predominate over silt or clay. The results obtained by the Research Division, however, show that the nature of the surface varies considerably from place to place and that there are layers of sand belts (containing sand and sandy silt), and clay belts (containing clay and dry silt) spread throughout the province. These belts, also, are of various thickness, upto 12 feet. Coarse sand underlies the whole area to a depth of 70 feet and the depth of soil itself is found in several boreholes to be varying from 30 feet to 200 feet and more (*vide* Plate 8). These layers are also impregnated with salt and abound in calcareous shells of animals.

On the whole, the sand belts are wider in extent than the heavy soil belts on both sides of the river valley and they nearly run parallel to one another, enclosing within them the deposits of clay.

On the right bank, the main sand belt lies continuously under the area, while on the right bank area these sand belts are not continuous but broken

and stretch for long distances from north to south, showing clearly the vagaries of the river and its various branches from time to time. Nearer the Eastern Nara and towards the south, clay belts predominate, showing how this stream, unlike the Indus river, deposited silt through its flood waters but did not leave its bed and cut through the clay belts later on.

These sands and clay belts indicate probably that the whole of the valley consisted originally of silt and clay, deposited by the flood waters from the Indus, which were ponded against the Kirthar Hills on one side and the sand-hills on the other and in a *still* condition and that " after the formation of this large expanse of clayey material, the river meandered through it cutting away the clay on its course and leaving sand in its place thus account-ing for the sand-belts which exist at present."[16]

Commenting upon the result of the investigations, Mr. Hawes says that a survey of the soil strata before the construction of any canals would have been highly advantageous in the matter of their alignment along clay belts, which are impervious and which would have prevented seepage and water-logging considerably.

There are also patches of Kalar (salt) bands here and there. (See Plate 9.)

*Special Drainage Features.*—One important feature of the drainage of this portion of the province is that it is confined to a comparatively narrow tract and, therefore, large and permanent marshes exist on both sides of the Indus on account of flood waters : (1) The Western Nara tract including the Manchar lake and giving rise to forests near Shikarpur and Larkana and (2) the depression from Khairpur to Umarkot now occupied by the Eastern Nara channel.

In the immediate neighbourhood of the river itself the ground is rather higher, because silt deposits are considerable and these also get covered up with wind-blown sands.

*(A) Western Valley Section.*

*Boundaries.*—This section chiefly comprising an old alluvial plain lies in the N.W. corner of the province. It is bounded on the north by the out-skirts of the Suleiman mountain, while the barren hills of the Kirthar form its western boundary. In the south the section narrows down into the Kohistan with the Manchar lake as the prominent boundary landmark. The line of the most westerly meanders of the Indus forms the natural eastern margin.

*Special Features.*—The topographical feature of the section is an un-even alluvial valley plain with but few outcrops of Tertiary limestone. It forms a wedge-like portion of low land between the Afghan Mountains and the Baluchistan Ranges and has a foundation of Tertiary strata, outcropping in a few anticlines. It is now nearly covered with old alluvium, which has

mainly been deposited by the Indus waters. Though almost flat, the country is not without gentle slopes here and there. Tabular uplands and well-marked Bhabar slopes of gravel are common between mountain streams. In other parts, owing to silt deposits, a kind of gently rolling character of Bhangar (aggraded river parts) in the form of mounds is developed. The mountain torrents get soon dissipated on reaching the plains, leaving gravel, and sand-dunes, small and large, lie scattered here and there. With the slightest obstruction from without or diminution of water within its body, the river deposits material in the flood plain. These deposits are more within the continually changing beds of the Indus than on the banks, and so they rise like dykes above ground. The slope of the plain is less than a foot per mile in places. This circumstance coupled with the fact that the Kirthar rocks, near the flanks of the mountain, dip down towards the interior, has caused a depression in the midland area. The Western Nara, the Manchar lake and the Aral river lie within this broad and shallow belt of the land, which is like a loop of the Indus river itself. This secondary waterway is also fed by the other streams draining the mountain system of the Kirthar during the rainy season. There is plenty of fresh-water underground, so that the Manchar lake, into which the main drainage of the area lies, has come to be the biggest fresh-water lake in India.

Desiccation, however, is very great towards the northern part. Although most of the land has been brought under cultivation by means of irrigation canals, there is a portion of desert land still left in the northwest corner. Owing to little rainfall, this part of the country between Jacobabad and the Bolan pass, thirty miles across, has remained a rainless desert destitute of any irrigation and is called the Pat. It chiefly consists of indurated light coloured clay, deposited by the Bolan and other mountain streams. The waters, charged with clay, are simply lost in the sands. Elsewhere, too, there are patches of salt and sand covering mounds, now much eroded by casual floods. Wherever there is any impervious clay covering the surface, Dhands or salt lakes are formed. Some of these are Dhand Saro, Dhand Daba and Dhand Changro.

A slope of gravel brought down by hill torrents, similar to the Bhabar at the foot of the Himalayas, extends along the edge of the Kirthar mountains forming a piedmont zone between the western mountains and the alluvium in the east.

*Soils.*—The soil within the area is very fertile. It is rich loamy alluvium, containing plastic clay, sand and salts. Old alluvium predominates in this section, and soil of the carbonate of saline and alkaline group is commonly found.

The silt, deposited by the river, is found to contain " particles of clay, slate, quartz sand, decayed vegetable matter, micaceous, talcose and chlorite schists, gneisses, etc."[17]  No doubt, these ingredients are derived from the rocks of the mountainous region, through which the drainage passes.  Even seeds of grass are brought down by the waters from time to time.

*Drainage.*—(1)  *The Indus river* is the very life of the land.  Its vagaries and instability, however, are proverbial.  The annual inundation period is its chief feature.  Its aggrading character within the region of our study, has been responsible for most of the geomorphological changes, which have taken place.  This subject has been fully dealt with in the second chapter.

(2)  Among the numerous " *Nais* " or mountain torrents, which are only occasional and not perennial, but which rising in the Kirthars, supply a large quantity of surface water and subsoil water to the  region, may be mentioned the following :—

(i)  *The Gaj Nai.*—This is the most important and longest of all and discharges water as much as 150,000 cusecs till February each year.  This *Nai* debouches into the Western Valley section, through a gorge and cuts through it in two narrow channels, one originating in Halawar near Kalat and the other in the Kirthar and has three exits in the northerly, southerly and easterly directions.  Its floods are heavy and  devastate large tracts of land.

(ii)  *The Mazarani Nai.*—This is in the Warah Taluka and is provided with a bund, wherewith its waters are held up in the form of a lake 10,000 sq. yards in area, for the purpose of irrigation.

(iii)  *The Khenji Nai.*—It is situated between the Upper Sind Frontier and the Larkana District.

(iv)  *The Dilan Nai.*—This is made up of three smaller Nais in the higher reaches and remains active during the greater part of the year, supplying water to nearly 5,000 acres of land.

(v)  *The Nari Nai.*—This drains a large part of the hilly tract and is joined by the Letan Nai.

(vi)  *The Sita Nai* and (vii) the *Salari Nai* are other minor water channels.

All these Nais flow ultimately into the Manchar lake.

(3)  *The Western Nara.*—From the nature of its level banks, its many meanders and absence of mounds on the sides, one is inclined to  consider this to be an old channel or at least a branch of the main river system, the Indus. It runs parallel to the mother stream for some distance.  It was projected into a canal by Col. J. G. Fife, R.E., sometime Head of the Irrigation

Department of Sind. This stream also finally falls into the Manchar lake. It is navigable during the monsoon season, especially between May and September, and is even preferred to the Indus during this period, for this purpose. The Manchar lake at the southern end can be taken as a local expansion of the channel.

(4) *The Gharo Stream.*—This is also supposed to be a natural river of a similar kind, but is deeper and wider than the Western Nara.

. (5) *The Aral.*—The most interesting of all water channels in Sind is the Aral. It is only 17 miles long and leaves the Manchar lake at its extreme southeast point, flowing eastward at first and then northeastwards, till it reaches Sehvan. Here it joins the Dunstarwah. After rounding a little, the combined channel turns southwards, till it reaches the Indus near Bhagothoro Station. More water goes into the Manchar lake through this short watercourse than through the long and worn-out stream of the Western Nara. It cuts the Indus almost at right angles. During the off-season, as the pressure of water decreases, the *Aral flows backwards and, reversing its action, becomes a drainage channel from the Manchar lake into the Indus.*

(6) *The Manchar Lake.*—By far the most important of the numerous Dhands or lakes in the region is the Manchar lake. It is only 8 to 9 feet deep and is a mere alluvial depression. It is bounded on the south by the Kohistan high-ground and fed by the Nara, the hill torrents and the Aral described above. As the level of the river bed is higher than that of the level of the lake during the season, the lake acquires a wide expanse, after an inundation, towards the north and the northeast, covering over 200 sq. miles—the largest fresh-water lake in India,—while during the off-season it remains restricted to about 14 sq. miles only by post-monsoon drying. *This characteristic of a periodically changing level, filling and emptying alternately, gives the valley some 186 sq. miles of excellent cultivable land during the cold months.* There is a scheme to drain the lake entirely in the cold season and thus provide, for Rabi cultivation, some 20,000 acres of arable land. (See Plate 4.)

*(B) Eastern Valley Section.*

This section of comparatively recent alluvium, covered over with sandhills and *Dhands* in parts, extends along the left bank of the Indus from the Khairpur State in the north to the delta proper and the Rann of Cutch in the south. It is bounded on the east by the meanders of the Eastern Nara, beyond which is the extensive desert region of the Thar. The drainage is very deficient in this section.

*Topography.*—Almost the whole of the section is overlain with recent alluvium, extending for many miles between the Indus and the East Nara.

In the northern parts, the levels are higher, more than 400 feet, in some places. There is a gradual fall in level, as we go southwards, till near the margin of the delta proper, the elevation is less than 50 feet. There is a similar gradient from the Indus river course eastwards towards the Nara river.

Large masses of land are covered with silt deposited by the river and sand blown in by the winds from the south and the southwest.

The whole surface is furrowed and cross-furrowed by the beds of ancient river channels, which have left their fertile meanders in many places.

*Relief.*—Apart from a few outcrops of limestone rising above the ground level, the area is flat. In the northern extremity of the plain, it just touches a range of hills, running north and south and rising to the maximum height of 413 feet above sea-level. Near Hyderabad in the middle and along the latitude 25° 21′ N., there is a similar flat-topped range of Tertiary hills 14 miles in length, but only 252 feet in height. These dip gently in the easterly direction and are scarped mostly on the side of the river. Still further south, near Tatta, are the isolated outcrops of the Makli Hills. They are of the same geological (Eocene) age, the rocks dipping gently towards the west and southwest. These few outcrops of hard rock embedded in the alluvium consist mainly of Nummulitic limestone of the Kirthar series, interbedded with green clays and gypsum.

Some idea of the accumulation of fluviatile and æolian deposits and the consequent elevation of the surface in this region can be obtained from the observations on the levels of the large hollows found between sand-hills and filled with flood waters from the Eastern Nara. These levels, in places 300 feet high, must have been " at least as high as the general surface of the Indus plain at no distant date."[18]

*Soil and Climate.*—The soil, mainly composed of recent alluvium, varies in composition from place to place and is rich enough to yield various kinds of crops. It is hard, sun-baked clay when devoid of water. A large part of the belt of land between the Indus and the Nara—the Doab, 70–80 miles wide—is very fertile, being covered with subaerial stream deposits. The types of soils found in the Western Valley section, *viz.*, Wariasi, Kachi and Chiki, are also found in this portion of the basin.

The full vigour of the hot and rainless season is experienced in the north, and the line beyond which the S.W. monsoon rarely reaches, is the latitude of 25° 20′ N. The rainfall varies from year to year and place to place but the average is about six inches. The climate is dry, on the whole, and typical of Sind.

*Drainage.*—The area lies between the two watercourses, *viz.*, the Indus on the one side and the East Nara on the other, the quantity of water in the latter depending upon the floods in the former and in a depression in the Bhawalpur State further north. There are no mountain torrents or other perennial streams, as in the Western Valley section.

*The Eastern Nara* is an old bed of an eroding river, which is lost. It runs almost parallel to the Indus showing the slope of the ground away from the main stream. Though it is called Nara, it is very wide and about 8 to 10 feet deep. Between the towns of Chundawah and Nawakot, the Nara or as it is there locally called the Hakra, skirts the Thar Desert. At Nawakot the river flows in two channels, the larger one running in a southeasterly direction to Wang-jo-got, where it joins the Puran, and the other continuing to skirt the Thar for about 30 miles, after which it joins the Puran below Wango Bazar. From the latter place, the waters of the Nara pass by means of the channel to the Puran to Lakhpat where after completing a course of about 300 miles from the head, they enter the sea near the Koree Creek. " Numerous *dhands* occupy the valley amounting in the aggregate to nearly four hundred, some of them being as much as three miles in length by one in breadth."[19] Enormous crocodiles live within the stream throughout the year.

It is a well-known fact that the Eastern Nara has lost its source of water owing to the divergence of the Indus and other rivers, especially the Sutlej, in the Punjab. The result is that a large portion of what was once fertile and well-inhabited land lies barren to-day.

Among the other old water channels of the Indus river now converted into irrigation canals are the Fuleli, the Gujah, the Gungro, the Pinjari and the Gunjree, all ultimately flowing into the numerous delta creeks in the south.

*Dhoroes.*—But one remarkable feature of the drainage in this section is the numerous *Dhoroes*, or dry water channels, found at short intervals. They are about 100–200 yards in width and from 2 to 10 miles long. They are without any apparent continuation at either end, and seem to merge into the sand-hills in the neighbourhood. They remain dry throughout the year, and so their beds are cultivated by lift irrigation. How these channels were formed is a problem, but from their nature they seem to have some connection with the main drainage-system of the country in the past. Lower down in the section, a few of these *Dhoroes* are continuous and reach as far as the sea.

(C) *Deltaic Area.*

*Limits of the Area.*—The deltaic area is limited by the coastal strip as far as Cape Monze in the northwest and by the numerous spurs of the Kohistan. Tatta marks the apex, which is also the limit of the tide waters ascending up

the river for about 60 miles.    Towards the S.E., the delta extends as far as the Rann of Kutch.   The shore line, scalloped with the numerous outlets of the river and in length about 125 miles, forms the base of the triangle.

*Outstanding Features.*—The deltaic area is of recent growth and is still growing.  The Khadar (low-land plain) of the Indus imperceptibly merges into it.  Unlike the Ganges delta, it is uncultivable, uninhabitable and unstable.  Within its limits the Khadar alluvium cannot be distinguished from the Bhangar.  On the other hand, the Ganges delta is not so well-defined as this one ; it is of the normal type and the river channel is bordered by high banks with grounds sloping away to swampy areas.

The changes in the Indus delta are caused by the changing character of the mouths of the river itself as well as the stormy nature of the sea during the monsoon season.  It is largely " furrowed by ancient river channels some continuous throughout the deltaic region and for many miles above it, but very many others in a more or less obliterated condition and traceable but for short distances."[20]   This is especially the case here, because towards the north of the delta, the surface is largely composed of loose micaceous sand, which facilitates shifting of water channels.   These changes are believed to have taken place during the last 900 years.[21]

At tide time the coastal strip is submerged upto an extent of 3 or 4 miles, so low and flat is its topography.  When the river is at its greatest height in the monsoon, the delta upto about 20 miles from the coast is flooded.[22] Extensive mangrove swamps come into prominence in creeks, when the tide waters are withdrawn.  The whole area presents a strange conglomeration of mud banks, sand dunes or *burkhans*, and swamps or lagoons.  These help in the process of altering the river-courses  within  the  delta.   Wherever old creeks have dried up, considerable masses of common salt have been left over and buried under the muds.  Sand has covered the low rugged limestone hills of Tatta and Gurrah like a crust.  Westward of the Gurrah Creek upto Karachi and Cape Monze, the shore is rocky but low and covered with sand.[23]

*History and Development of the Delta.*—A very large part of Sind can be taken as ancient delta country.  From some of the old maps of Sind we find that the delta has grown considerably even during historic times, that the Indus has swung several miles on either side except at certain fixed points, in its course through the land, and at one time flowed due south into the Gulf of Cambay, that its flood waters flowed into the Eastern Nara, and that its mouths are changing both in number and position.  In the oldest map of Ptolemy there are shown seven branches flowing out into the Arabian Sea at

points quite different from those found in later maps.   The oldest head of this growing delta can be easily placed at Hyderabad.   Later on, Tatta became the apex and now as it is considerably advanced, it has shifted several miles southwards.   Towards the east, the delta receives but little water from the Indus.

The history of the delta has been recorded in the various mouths of the Indus, ancient and modern.   The Koree mouth seems to be the oldest, it being the opening of the Eastern Nara or the Puran at one time and the Fuleli at another.   Upto the beginning of the 18th century there were eleven mouths noticeable with the Baghiar and the Sita as its two navigable arms. The earthquake of 1819 produced some changes.   The Koree Creek became widened considerably due to subsidence.   Shahbunder on the Begana or Mol which was a prominent port, was closed down, the Bhagia was deserted and Kukaiwari and Khedewari Creeks came into prominence about the year 1837.   In 1867 Kukaiwari was blocked up with sand and the Hajamro, formerly known as the Sian, became the chief river port.   Before Karachi and Kotri were opened up for traffic by rail, the Piti and the Juna Creeks served all the merchant ships and ships of war.   Gizri was also a port till recently.   (See Plates 14.)

The growth of the delta is marked more towards the southwest.   Many of the ports which stood on either side of the river in the past suffered on account of the shoals and sand banks thrown up near them by the sea, which during the monsoon season becomes heavy and tumultuous.

The present head of the Indus delta lies at the bifurcation of the Ochito and the Haidari and the principal creeks at the present day are thirteen in number.

The mineral character of the muds near the Keamari harbour is the same as that of the Indus silt.   These muds are, therefore, drawn in by the S.W. monsoon current as a result of the oblique action of sea-waves.[24]

*Comparison with the Nile Delta.*—The growth of the Indus delta is, however, not so rapid as that of the Nile, the reason being that the Mediterranean Sea is calmer than the Arabian Sea.   The shore lines are being vigorously worn down by the waves which have a disastrous effect on the Indus delta. The discharge of solid matter in the case of the Indus is $217\frac{1}{4}$ million cubic yards per year, against 240 million cubic yards per year in that of the Nile.[25]

*Soil and Vegetation.*—Low and swampy shore lines overflowed by tides mark the outer boundary of the area. Above this line, sand-hills predominate, while still higher up the soil is argillaceous, mixed with clay and sand, which

gets hardened on exposure to the sun. It is also impregnated with common salt.

In the marshy area, good pastures of tall grasses are available, while tamarisk and mangrove grow in the interior. There are also a few fertile fresh-watered patches between the river branches and above the swampy plains, in which red rice is grown.

### IV.  Province (III) : Desert Province.

*Limits and General Description.*—This province forms a part of the Rajputana Desert. It is called the Thar-Parkar. It lies within the desert belt of the tropics, between the latitudes 24° N. and 28° N. Its western limit is fixed along the course of the East Nara or Dhoro Puran, as far as the latitude 26° N. From here it extends northeast along the edge of the sand-hills as far as the Bhawalpur State. The eastern boundary of the region is only political, a large portion of the Rajputana Desert in the neighbourhood being of the same origin and category.

The province is distinct from the alluvial plain on its west, as it is on higher ground and almost wholly spread over with sand and *Dhands*. It slopes a little from east to west, but rises in level as we go from north to south. It is barren even when parts of it lie within a few miles of the river.

*Not a True Desert.*—This province cannot be called a typical desert, however, as it is neither entirely barren, nor rainless. It is also not quite uninhabitable. On the other hand, the presence of many furrows of ancient river beds especially towards the north and of ruins of towns and villages along them and the course of the Nara river shows that this region was far more prosperous in bygone days than it is to-day. Cattle, camels and sheep still live on its present scanty water and vegetation. To some extent parts of this desert are being gradually brought under cultivation, so that there are now found zones of gradation all around, especially in the Pat area.

*Origin of the ' Desert' Province.*—The desert conditions are due to several circumstances :

(1) *Considerable Sub-aerial Denudation.*—Whatever solid rocks existed within the area, they have suffered destruction through " the process of desquamation " producing characteristic topographical features " of sand blasted, treeless landscapes, one sees for miles around under a clear, cloudless sky."[26]

The diurnal as well as seasonal variation of temperature is considerable and there is no organic or chemical agency to turn this debris into soil or humus.

(2) *Æolian Deposits.*—There are enormous deposits of wind-blown sand, transported from the shallow Rann of Kutch and the coastal area in the south of the Thar. Sand-drifting takes place on a gigantic scale during the S.W. monsoon season. Rounded grains of quartz, felspar, mica and hornblende, found among sand, show the disintegrated parent igneous rocks from the Himalayas and the Aravallis, having been transported here in past ages. The presence of calcareous grains point towards the decomposition of sea shells on the coast lines.

(3) *Vagaries of Rivers.*—The whole region, entrenched with old river beds, suggests that in the past it must have been favoured with more water and better drainage.

(4) *The presence of salts* like chloride of sodium (common salt) in the soil, renders the land barren.

(A)  *The Pat Section.*

The force of the S.W. monsoon is not felt here so much as in the Thar Desert section described below.[27] The longitudinal ' bhits ' or sand-hills are haphazard and transverse ridges lie across them invariably. The hills are not so high as they are in the south, not many of them, being over 300 feet, but they are large and generally N.-S. On the whole, the area is less rugged and more flat.

The soil is loose and sandy, presenting a dry and arid appearance and lies on fine clays and silts impervious to water. As a result of this, there is no leakage of water from the streams and canals running through the alluvium. Any rainwater, that falls into the hollows between the sand-hills, is held up and *Dhands* or lakes charged with *reh* or ' Kalar ' are formed.

Some parts of the Pat, especially in the Nawabshah, Sukkur and Khairpur State districts, have been brought under cultivation and the sand-hills more or less eliminated upto the contour line of 200 feet. Owing to these parts being higher than the main water channels, irrigation is maintained by ' lift ' and not by 'flow' method.

The greatest peculiarity of the Pat Section is that even with very little rainfall (average 3 inches) or flood waters, the hills are covered with a surprising amount of vegetation, shrubs, etc., for cattle to live upon and the valleys are filled with rank grass or cultivation.

*Dhands.*—Salt water or natron-producing *Dhands* are a characteristic of this region[28] and an evidence of the former sea communicating the interior. Within the deep hollows, between sand-hills, called Kochurs, water charged with salts percolates through the sand, forming the salt lakes. They are elliptical, low lying and flat and oval-shaped basins, not deeper than 10 inches

or so with their long axis parallel to the main ' bhits ' and, therefore, to the wind direction. They serve as " huge flat-bottomed evaporating pans " and are without any outlets. Both the ' bhits ' (ridges) and ' talis ' (valleys) are frequently covered with vegetation, as there is some rainfall (at times 5–10 inches or so) in the locality. Although much of the rainwater is soon evaporated due to the heated mass of sand and soil, some of it percolates to the impervious soil below, and is held up for sometime or ejected in the form of salt springs (*Sim*).

The factors, controlling the salinity and desiccation of the *Dhands* are (i) withdrawal of flood waters, (ii) approach of summer, (iii) blowing of loose sand, (iv) salt-charged soil.

Another peculiarity of the *Dhands* is that, after a huge inundation of the area, they lose their aloofness from one another and are joined together for the time being. Later on, when the flood waters subside, they regain their individuality and aridity and grow in salinity.

There are many such *Dhands* in Sind. In the Khairpur State alone there are some 129. The following are a few typical *Dhands* :—

Haleji, Jhimpir, Dhore, Kinjhar and Sonahri.

The following analysis of the salts is typical of the salt-lakes in Sind[29] :—

Name of Dhand : Bagarwaro (Khairpur State) $CO_2$—18·48, Cl—5·3, $SO_4$—19·3, $Na_2CO_3$,—33·4, $NaHCO_3$—17·6, NaCl—8·8, $Na_2SO_4$—28·6, Carbonate-bicarbonate index—1·8.

Some of these salts are produced by the interaction of acids on the soils and sands of the locality.

## (B) The Thar.

This section is a wide expanse of several thousand miles, entirely covered with sand except for some elevated parts. It consists of " a tract of sand-hills, resembling the waves of a troubled sea," generally higher in the western than in the eastern parts. There are salt encrustations often about an inch deep.

The direction of the sand-hills, some of which exceed 500 feet in height, is parallel to the prevailing wind (*i.e.*) N.E.-S.W. or E.N.E.-W.S.W. further up. Near Khipro, as the force of the wind currents diminishes northwards, the direction of the ' bhits ' or hills also changes to N. E. by S., and further northwards to N.N.E.-S.S.W., until finally they strike N.-S., as the zone of gradation is approached. (See Plates 1 and 16.)

These longitudinal hills are mostly restricted to the sea side and western borders of the Thar, as the wind current is stronger locally. The ' bhits '

are unconnected and lie in parallel ridges. Between them, the original alluvial soil lies exposed.

Wherever the quantity of sand is great, there are formed plateaus (*dra-in*) of deep sand continually changing shape with the direction of the wind, until they grow into " a sea of sand with beautiful irregular curves of hills and hollows".

*Paucity of Water.*—During the monsoon, the southern parts of the desert are flooded by sea-water and also by fresh-water received from swollen channels after rainfall. But in the dry season and near the Nara water is generally found at from one to two fathoms from the surface ; it is a little brackish, but on account of scarcity, people drink it. " It is obtained by digging temporary wells, at the bottom of which a wooden foundation of the shape of a wheel is placed, and the sides are then built up with wicker work of green branches and brushwood, to prevent the soil falling in ; the water thus filtering through the sand is sweet, so long as the wells are regularly worked."[30]

As we go further inland, the conditions change. " In the interior the depth of the well varies corresponding to their distance from the Rann ; where of any considerable depth, they are built up with burnt bricks, stone not being procurable and wicker work too insecure ; 30 miles inland the wells are 60 yards deep." In Chhachhro, however, the water-table goes down to 300 feet and more. Surface water is rare in this region, although *Tarais* or tanks are constructed in some parts for collecting rain water.

*Rock Exposures.*—From a few outcrops of Malani rhyolite, Cuddapah trap and crystalline complex in the Rajputana Desert, one may expect a wide extent of solid geology buried under sand in this section. " It is quite probable that a large extent of fossiliferous rocks, connecting these isolated inliers, is buried under the desert sands."[31]

The only prominent outcrops within the arid district of Nagar Parkar that have escaped complete denudation or burial are those of the Kalanjhar (Kalingar) Hills rising to 1,169 feet above the sea-level. But these isolated hills differ materially from every other rock occurrence in Sind. They belong to the Dharwar and other pre-Cambrian systems and are, therefore, associated with the neighbouring Aravalli range, with syenite as the main rock-component. Evidently they form the extreme end of the once stupendous mountain system of Rajputana, which is now so greatly degraded and denuded.

*The Parkar District.*—This part of the desert, situated in the south-east corner, differs from the rest in the matter of rainfall, which though variable, ranges from 4 inches in Sanghar to about 15 inches in Nagar Parkar.

While at one time there is practically no rain (*e.g.*) 4 cents at Khipro in 1899, at another there is heavy and torrential rainfall (*e.g.*) 41 inches at Mithi in 1913. There are a couple of perennial and some seasonal springs in the region and the soil is a medium sort,—a mixture of stiff clay and fine sand and is cultivable for good Rabi crops, *e.g.*, Bajri and wheat.[32] Another difference is that the sand-hills of the Thar are replaced by ranges of hills composed of solid rock, mentioned above.

### V. *Economic Resources of the Lower Indus Basin :*

### (I)   *Western Highlands.*

(A)   *Kirthar Mountains.*

(1)  *Building stones* of great durability in the Kirthar Range, as well as in the Kohistan, especially in the Ranikot beds, at Jhirak, which yield light, yellowish or brown and fine-grained limestone, of an excellent character. The blocks are large, as the joints are far apart.  Good ferruginous sandstone of the Nari series is also available near Jungshahi.

(2)  *Alum* is obtainable from pyritous shales found in the Gaj beds near some Nais.  The manufacturing process consists in " a rude lixiviation of pyritous shales in the Gaj, Ranikot and Nari groups on the flanks of the mountains, the necessary potash required being obtained from the ashes of certain plants."[33]

(3)  *Quicklime* is prepared on a large scale from local limestone quarries in the mountains.

(B)   *The Kohistan.*

(1)  *Lignite.*—A layer of lignite, a brown coal among the Ranikot beds (shales and sandstones) in the Laki Range has been already referred to.  Two seams were found at Linyan, 27 miles N.N.W. of Kotri and 15 miles from the present course of the Indus.  One of these was proved to be lenticular, though of good thickness.

Although the coal deposits were found to be meagre at the time, it seems that sufficient prospecting has not been done in recent years.

(2)  *Petroleum.*—There was also an experimental boring for petroleum made at Sukkur in 1893–95 but it did not prove successful.[34]  An experimental well was dug by the Burmah Shell Co., near Khairpur Mirs in 1922–23. But the results are unknown.   Oil indication has also been noticed at Drigh Road, within a few miles of Karachi.

(3)  *Iron Ore.*—Brown hœmatite is found embedded in limestone and sandstone.  At Tatta smelting of iron was practised to a considerable extent in the past century.

(4) *Road Metal.*—Limestone is generally used as road metal, but there is plenty of trap in the Laki Hills, though it is somewhat decomposed. A bed of trap 40 feet thick is found interstratified in sandstone above Hippuritic limestone on the hill called Bor, south of Barrah, 13 miles N. of Ranikot. Another band of trap is on *Cardita beaumonti* beds, stretching 22 miles from Ranikot to Jakhmari 17 miles south of Sehvan. It is 40 to 90 feet thick. The decomposed basalt contains nodules of quartz, chalcedony and calcite.[35]

(5) *Gypsum.*—Gypsum is found also on top of Gaj Hills in the Kohistan area.

(6) *Clays.*—Coloured sands and clays, white, red, and brown occur in the Laki Hills near Bhagothoro.

### *(II)  Economic Resources of the Lower Indus Valley.*

*(A)  Western Valley Section.*

(1) *Agricultural produce.*—This is the mainstay of the region. Two crops are reaped as follows :—

| Juari |   |   |   | Wheat |   |   |
|-------|---|---|---|-------|---|---|
| Bajri | } | Kharif |   | Tobacco | } | Rabi |
| Rice | } | (Summer) Crop |   | Barley | } | (Winter) Crop |
| Cotton |   |   |   | Oil Seeds |   |   |

With the steady and systematic water-supply from the Lloyd Barrage great improvements are being made in these crops and fresh cultures introduced. Cotton has come out to be the best in India.

(2) *Forests.*—Along the banks of the great river there is a luxuriant growth of riverain forests, some of which have extended inland along the *bunds* and canals. Occasionally a whole forest disappears due to erosion of banks by flood waters. Babul (*Acacia arabica*), Kandi (*Prosopis spicigera*), Bahan (*Populus euphratica*), Tali (*Dalbergia Sissoo*) and tamarisk (*Tamarix gallica*) grow plentifully.

*(B)  Eastern Valley Section.*

(1) *Salt beds.*—Capt. Baker drew the attention of Sir Charles Napier in a letter to him on 18th July 1844 regarding the existence of very extensive salt beds near Allah Bund, in connection with the lower part of the Puran. From Raoma to Wanga Bazaar large beds of salt, 5 to 6 feet deep, were discovered by Mr. Hodges.[36] (See next Section.)

Within this area there are valuable salt deposits. About a mile east of Goonee and extending 20 miles by 15 miles, terminating at Kotri between latitudes 23°–24° N. and about the longitude 69° E., there exists a bed, 3 feet thick nearly 929,280,000 cubic yards, equivalent to 1,484,151,430 tons, if the specific gravity of it is 2·130. This bed was discovered by Lt. Burke, R.E.,

Executive Engineer, P. W. D., Sind Division, in 1847, while travelling from Sind to Kutch. In a letter, dated 7th March 1847, to Major Peat, Superintending Engineer, Sind, he described the bed as follows :—

" For the first few yards, it appears as a ridgy layer with bunches and is but a few inches in thickness ; but the thickness rapidly increases, and the structure is so hard and crystalline that it required some little time and labour to detach the smallest fragment with the only available tool I had with me, *viz.*, a strong hunting knife. The hoofs of a horse made no impression on its surface. This was a sandy colour, owing to the presence of a very slight film of drift dust or sand, which has been absorbed by the deliquescent quality of the salt. Crystallised knobs or bunches, of the same exterior colour as the general bed, occasionally rose about the surface and a few of these, having been recently detached, showed the dazzling and highly crystallised interior structure of the mass ; less homogeneous and compact but perhaps clearer and more brilliant than that of Chesire, or of the Punjab."[37]

Lt. Burke also secured the opinion of Surgeon A. H. Leith of the Bombay Medical Establishment, as regards the quality and utility of this mineral :—

" It is just the same as the salt obtained by evaporating sea-water,— the salt that is called Bay Salt : it is not so pure as rock salt, because it contains a little sulphate of soda, very little and of no consequence and also some muriate of magnesia, which later renders it a little bitter, but it can readily be removed by washing the salt in fresh-water : but as it is, I have no doubt, it would find a ready market, for it is very much cleaner than what is made in the Government salt pans about Bombay."[38]

No more is heard in recent years about this precious deposit, which in the opinion of its discoverer : " Would supply a population of one hundred millions for one thousand six hundred and sixty-two years, at an annual allowance of 20 lbs. per head."

(2) *Fuller's Earth.*—There are intercalations of this clay in limestone on the slopes of the Ganjo Hills, near Hyderabad, and also in the hills near Sukkur-Rohri, Jerruck and Tatta. It is a pale greenish clay used for washing cloth, etc., and is also eaten by pregnant women as a soother.[39]

(3) *Gypsum.*—Gypsum is found on top of Gaj Hills in the region, in places 3 to 4 feet thick. Dr. Buist, in 1852, referred to these deposits as a mineral for making Plaster of Paris and using the same for casting lattices and open-work screens for ventilation on tops of doors.

(4) *Pottery Clays.*—The pottery works of Hala, Hyderabad, Tatta and Jerruch as well as the encaustic tile manufacture of Bulri and Saidpur make use of these clays.

(5) *Flint.*—Cores of flint occur embedded in Nummulitic limestones of the hills near Sukkur and Rohri.

(6) *Agricultural Produce.*—Large crops of Wheat, Juari, Bajri, Cotton, etc., are obtained.

(7) *Medicinal and other plants.*—Plants yielding drugs, chemicals such as soda, gums (myrrh), dye-stuff and tanning ingredients, grow in abundance.

(C) *Deltaic Area.*

*Salt Deposits, Fisheries, etc.*—(1) Within some of the creeks there are salt deposits of (*e.g*) Surganda salt beds, 7 miles on both sides of the Sir Creek. Captain Baker, Superintendent of Canals and Forests, in a letter, dated 18th July 1844, to Sir Charles Napier, also referred to other extensive salt deposits near the Allah Bund in the southeast. "I take this opportunity of bringing to the notice of H. E. the Governor of Sind that there are pools and valleys, connected with the lower part of the Puran, abounding in pure salt; many of the pools near the Allah Bund contain superficial deposits of this substance; but Mr. Hodges, Assistant Surveyor, who surveyed from Raoma to Wunga Bazaar, met with large beds of salt to a considerable extent, and five or six feet deep. Should Government consider the subject worthy of attention as a source of revenue, it would appear from Mr. Hodges' description that the salt may be obtained in almost any quantity, and of the purest kind."[40] For several reasons, among which may be mentioned, the opposition of the Bombay, Cheshire and Liverpool merchants in their own interests, these salt deposits were not utilised at all.

Another salt deposit of a similar character was noticed "in the delta of a classic stream—between the Gora and Koree mouths," by Lt. Burke in 1848. He thought that to be "a vast and practically inexhaustible deposit."[41] A sample of it was carried to Calcutta in 1855 as ballast in a cargo boat. Later on, a company was also formed. The following[42] is the analysis of the salts given for comparison :—

| Salt | $NaCl_2$ | $MgCl_2$ | $MgSO_4$ | $CaSO_4$ |
|------|----------|----------|----------|----------|
| The above deposit | 99·7352 | 0·2647 | 0·00 | Trace |
| Cheshire | 98·2500 | 0·7500 | 0·00 | 1·55 |
| Lynimgton | 93·7000 | 1·1000 | 3·5000 | 1·50 |

It is to be remembered that the younger Tertiary rocks also are inpregnated with saline material due to the original (connate) sea water in the sedimentaries.

(2) *Saltpetre* can be extracted from soil, impregnated with nitrogenous matter. It commanded some trade with the East India Co., in the latter part of the 18th century.

(3) *Sea-salt*: About 88% of the Sind salt is obtained from sea-water, while only 12% from the Saran and Dilyar deposits on the edge of the great desert in the Desert Section.[43]

(4) *Pearl fishery*, as a source of revenue, was known to the Ameers of Sind and the industry was also developed in the early British days: Mr. John Macleod, Collector of Customs at Kurrachee, in a memorandum submitted to Government on 31st December 1847 says: " In the salt water inlets along the entire sea coast of Sind, a thin-shelled variety of the oyster exists, producing a seed pearl. It is most frequently found on mud banks left dry at low tides. The pearl is of very little value compared with that produced by the Ceylon and Persian Gulf Fisheries, the price of the latter ranging from Rs. 1,000 to Rs. 15,000 a tola while the former seldom realises more than Rs. 15 a tola. From the supposition that it possesses invigorating powers, it is used here chiefly as a medicine. The larger grains are occasionally made use of as personal ornaments: the smaller ones to intermix with the valuable Bahrein pearls, in which manner they are kept in bags by the Bombay merchants, as a means of preserving their lustre."[44]

Side by side with this, there is good scope for a *sea fishery* also on the Sind coast.

### (III)  Economic Aspects of the Desert Province.

The natron-producing lakes already mentioned are the principal centres of industry. The mineral is an impure sesqui-carbonate of soda mixed with common salt, of which thousands of camel loads are exported from the *Dhands*. Cheroti or gypsum is also extracted from Ghulam Nabi-jo-Got, while Khara Chanio or soda and trona (*chaniho*) are also met with. Soda salts can be prepared from the ashes of the halophytes or natron-producing plants, growing in the region, by the process of lixiviation. There are also a few salt lakes in the southern portion of the Thar Parkar District besides Saran, Darwari and Gaganwari beds, in which a good amount of salt is available.[45]

Wherever rain water is lost more by evaporation than actual run-off, subsoil and internal lake brine yield salt, which is merely arrested on its way to the sea. Brine-impregnated subsoil also yields common salt.[46]

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THE history of the Indus River goes far back into the mists of time. A large part of the Siwalik deposits of the Outer Himalayas led the geologists, E. H. Pascoe and G. E. Pilgrim, to believe that there must have existed an old river in this region, called the Indobrahm by the former[1] and the Siwalik river by the latter,[2] before the Himalayas came into being. (See Plate 12.)

## I. Geological History.

Geologists have also generally recognised that in Asia there is a general trend of East-West river valleys (e.g.) the Sangpo, the Hwang-Ho, the Yangtze Kiang and the Si Kiang.[3] The rivers of northern India in their early stages show the same tendency. There is, therefore, no doubt that there flowed, in the Indo-Gangetic depression, a single river, at first flowing in the S.E.—N.W. from Assam to Kohat along the foot of the Himalayas; but, later on, its drainage was altered and broken up, with the rising of that mass of Central Asia like a tremendous block. These mountains also gradually pushed the Tethys Sea further and further back.

The following are some of the indications concerning the history of the drainage of this region, arising out of a study of the Siwalik Boulder Conglomerate.[4]

*The Parent River.*—" The peculiar character and distribution of the Pleistocene boulder Beds of the Siwalik series are capable of explanation only on the supposition that they were laid down in a rock basin, formed in the valley of a large river by upheaval and the consequent formation of a dam across its course. Since in Jammu and Kangra these boulder beds attain the enormous thickness of 5,000 feet and disappear quite suddenly to the N.W. of this area, while to the S.E. they gradually diminish in thickness and are feebly represented as far as Bhutan, it follows that such a dam must have been situated N.W. of Jammu and that the river flowed along the foot of the Himalayas from S.E. to N.W. In Eocene times, when the sea covered the whole of the Western Himalayas, such a river must have risen on a watershed connecting the Rajmahal Hills to those of Shillong and the upper valley of the Brahmaputra, and continuing into China. A tributary of this river, draining the Eastern Himalayas, may, at a later period, have become the main river of northern India. The author considers that the complicated drainage system and breadth of the Mahanadi so disproportionate to its length, as well as the entire absence of any fluviatile deposits older than sub-recent, such as we find on the Irrawaddi, point to Pliocene submergence of much of its former valley and to a much wider extension of the Indian peninsula, over what is now the Bay of Bengal, from the Eocene onward, than is

the case to-day. Therefore, powerful rivers flowed south rising on the same watershed which is mentioned above. These may have cut back through it so that when a final uplift, on a more colossal scale than any that had preceded it, actually reversed the flow of the river in the basin of which the boulder conglomerates were deposited, the water flowed into the channels of the southerly flowing rivers which were ready to receive it. The V-shape of many of the Himalayan rivers along a certain portion of their course (the point of the V facing N.W.) is significant as evidence that the northern arms of the V's represent tributaries flowing in the normal direction which they would take to join a great northwesterly flowing river. The Gangetic alluvium, thick though it is, has all been deposited later than this period in the valley of rivers with a normal gradient, as the result of annual floods depression continuing simultaneously with the addition of flood material and sediments."[5]

*Discoveries of the John Murray Expedition.*—This theory of the Siwalik river bed may probably gain some support by the observation of the John Murray Expedition of 1933–34, in exploration of the continent of Lemuria or Gondwanaland, which is supposed by geographers to have once existed in the area now occupied by the Indian Ocean and other connecting waters. Not much light has been thrown by the explorers on the matter of such a vast continent, but the existence of *certain submarine ridges and gullies* has led them to believe that there was an extension of the mountains of the Kirthar and the Aravallis systems along with *a huge river valley, which have now gone down into the northern parts of the Indian Ocean.*

*Subsidence of the End Portion of the Indus Valley.*—Lt.-Col. R. B. Seymour-Sewell, the leader of the Expedition, describes in a statement to the press :

" Between Ras al Hadd and the Indian Ocean in the neighbourhood of Karachi, the echo-sounder clearly revealed the presence of a submarine ridge that runs westward towards the entrance, to the Gulf of Oman, more or less parallel to the hill ranges of Baluchistan and Makran. To the south of this ridge and separated from it by a level plain with a fairly constant depth of 1,850 fathoms lies a second ridge that runs towards the southwest, and immediately to the southeast of this is a deep gully, bounded in its turn by the edge of a plateau that slopes gradually downwards towards the southeast.

" The bottom of this gully lies 2,000 fathoms below the surface of the sea and its general character reminds one strongly of a river bed. It seems to me that we have here either the now submerged bed of the Indus where it flowed into the Arabian Sea along a line to the northward of its present course or perhaps the mouth of the great Indobrahm River, the existence of which was postulated by Pascoe and Pilgrim."[6] (See Plate 15.)

It is, therefore, probable that the Indus had its connections with the ancient drainage of the Indo-Gangetic plain in the pre-Himalayan epoch.

*Breaking up of the River : Indobrahm.*—When the process of the up-heaval of the Himalayas finally ceased in the north towards the end of the Pliocene period, this great river must have broken up into two systems, *viz.*, the Indus with its tributaries on one side and the Ganges on the other.

*The Process of Severance.*—How this severance of the Siwalik river into the Indus system and the Gangetic system took place, is an interesting history. D. N. Wadia[7] states :—

" The most important post-Siwalik event was the dismemberment of the channel of the great Siwalik river, which hitherto had flowed in the northwest direction, from its head waters near Assam, through the whole length of India to Potwar, and thence to the head of the receding Sind Gulf. The differential earth-movements which elevated the Potwar basin into a plateau, converted the northwest section of the channel into a separate independent drainage basin, with the Sutlej as its most easterly tributary. Hitherto the combined river had travelled to its confluence with the Indus along a track which was a northwestwards prolongation of the present course of the Jumna, thence *via* the present bed of the Soan, to the Indus in the vicinity of Makhad. After these elevatory movements and the separation of its N.W. section, the remaining upper portion of the main channel, according to the views of Pilgrim and Pascoe, was subjected to a process of reversal of flow, its waters being forced back by the Potwar disturbance to seek an outlet into the Bay of Bengal along the aggraded, more or less levelled sub-montane plains. In this process of reversal Sir E. H. Pascoe attributes the vigorous young affluents belonging to an opposing drainage course cutting back, beheading and capturing piece by piece, the main channel and ultimately deflecting its waters to the new channel with a reverse direction of flow. This severed upper part of the old Siwalik river became the modern Ganges, having in course of time captured the transversely running Jumna and converted it into its chief affluent. The transverse Himalayan rivers which are really the oldest water-courses of North India, older in many cases than the mountains they traverse, continued to discharge their waters into this new river irrespective of its ultimate destination, whether it was the Arabian Sea or the Bay of Bengal. During the Upper Pleistocene epoch some interchange took place between the easterly affluents of the Indus and the westerly tributaries of the Jumna, by minor shiftings of the watershed, now to one side now to the other. There are both physical and historic grounds for the belief that the Jumna, during early historic times, discharged into the Indus system through the now neglected bed of the Saraswati River of Hindu traditions, its present course being of comparatively late acquisition."[7] (See Plate 12.)

The present dry beds of the lower parts of the Ambala streams, and also those of the Gagger, the Hakra and the famished condition of the Eastern Nara and other Dhoroes in Eastern Sind, with a large number of ruined towns and villages now buried under sand along their channels, indicate that there must have passed through these desert tracts a large river making them fertile and prosperous.

This diversion of drainage from the Indus to the Ganges must also have been gradual. A certain species of dolphin lived on fresh-water food in the original river. Then when a depression between Rajmahal and Assam took place, and the drainage partially escaped into it, this fauna must have also passed into it. R. D. Oldham holds very strong views regarding the original westward flow of the Jumna-Gangetic system. He says, " The diversion of the drainage from the Indian Ocean to the Bay of Bengal must have been a gradual process, whose final stage, the permanent diversion of the Jumna into the Ganges, may even have taken place within the historic period. Before this, the waters of the Jumna must have flowed alternately into the Ganges and the Indus, or that dry river channel which can still be traced through the desert. In its latest stage, it probably, like the Casiquiari in South America at the present day, divided its waters between the eastern and western drainage, but now no further change can take place, for the river has cut its channel deep below the general level of the plain, and must perforce remain a tributary of the Ganges."[8] Thus the Indus system became quite independent from the eastern drainage system, and remaining partly antecedent (i.e.) pre-Himalayan and partly consequent, it has cut its own course through the mountains after the first uplift in the Pliocene age.

*The Indus in Sind.*—The Indus in Sind is the lower part of the Indo-brahm, ultimately falling into the Arabian Sea, while the Indus of the Himalayas is an old tributary of it, discharging into it at Attock. As it is now in an exceedingly aggraded stage, its present channel through Sind is not the same as was in past geological and early historic times. It might have flowed through the now desert region straight into the Koree Creek, owing to its greater volume of water than at present. The rather eastward position of the submerged Indus gorge in the Arabian Sea and the physical features of Cutch also point to this course of the river in the Pleistocene period.

## II. Recent History of the Indus.

The source of the Indus was discovered in 1907 by Hedin in a sacred spring, called the Singikabad, near the Manasarover lake on the north side of the Trans-Himalayan Range, N.N.E. of Kailas and 16,946 feet above the sea-level. This position of the source, in a lacustrine region (lat. 32° 20′ N., long. 80° E. in the heart of the snowy peaks), suggests the birth of the

river to be antecedent to that of the Himalayas. Had it been a consequent stream, after the upheaval in later ages, it would have flowed directly south. As it is, it takes its original course still towards the N.W. for a considerable distance. While it thus emerges from the glaciers of the great group of Kailas Mountain peaks, it secures the waters of three affluents : (1) the northern tributary pointing the road from Ladakh to the Jhalung gold-fields ; (2) the southern Ghar forming a link in the great Janglam, connecting Ladakh with Lhasa and China ; and (3) the Shyok and the Shigar together with innumerable glacier-fed streams. So far the Indus has travelled through 530 miles of its bed between the grand chains of Ladakh to the north and the Zaskar Range, which is the main snowy range of the Himalayas to the south. Except for a short distance in the S.W., it pursues its usual course in the N.W. direction. The combined stream then reaches the Rakaposhi Peak. Here the Indus again turns to the S.W. for the last time and piercing the mountains transversely, between the Gilgit and the Hunza, drops suddenly from 15,000 feet to 4,000 feet level.

Soon it touches the Gilgit stream, emerging as it does from perhaps the grandest gorge in the world. Thus, nearly 500 miles of surpassing mountain scenery are passed in north Kashmir. Only a few miles below this, the Indus crosses the mountains of Kohistan and Hazara, receiving its tributes from either side, until finally it advances into the Punjab plains below Darband in the latitude 30° 10′ N., after flowing for nearly 850 miles from its source.

Uptil now, the Indus has received the drainage of the Himalayan mountains only. Soon at Attock the Kabul brings down the waters from the Hindu Kush and then the Kuram, the Tochi, the Zhob and the Gomal give their share too. Although still some 2,000 feet above the sea-level, the Indus becomes here a navigable river, having left all rapids and deep wild gorges behind. Nearly 450 miles further south, the accumulated waters of the Panjnad (five rivers) of the Punjab rush into the Indus River.

*Lower Reaches.*—As the numerous tributaries of the river in this plain stage flow through drier and drier areas, they become smaller and smaller and their currents become slower and slower. Perforce they have to abandon old aggraded channels and cut new ones through their own deposits of mud, sand and gravel. While in their upper reaches they have deeply fixed channels, in this lower plain stage even in the Punjab they have varying sand-banks and stifled watercourses. Thus, on both the banks of the present Indus bed, numerous ancient channels of this kind have been discovered from long stretches of coarse gravel or sand-banks.

*Entry into Sind.*—The single stream, thus strengthened at one point and starved at another, and still called "Darya" or sea, by the local

inhabitants, now enters the province of Sind. Instead of increasing in volume it dwindles down to less and less with its basin narrowed down and its affluents growing insignificant. It receives no tribute from any other perennial stream in the long stretch of over 300 miles in Sind, as there is little rainfall on the Western Highlands and the surface drainage is so poor. Its entry into the province is now heralded with a rush through the gap or gorge between Bukkur and Rohri in the limestone rocks. Here the topography is quite peculiar :

"The Indus in its course through Sind," says R. D. Oldham, "flows between banks that are raised above the general level of the country which slopes away on either side. This is a feature common to all rivers which are raising the level of their alluvial plains by the deposit of silt but at Bukkur, the Indus exhibits a feature which is exceedingly rare if not without a parallel, in the case of any other river, for, here it flows at the higher level through a gap in a range of hills surrounded on either side by alluvium at a lower level than that of the river where it passes through the gap."[9]

After this rush of waters through the gorge, a comparatively calm flow in the S.W. direction with the two arms, the Eastern and Western Naras, is now assured. The overflow lake of Manchar, with its safety valve, the Aral River on the right, and the various old channels of the Puran, Dhoro Naro, Gungro, Fuleli and Pinyari into which it rushes during the season on the left bank, help to complete the picture of the Indus in its Lower Basin. By this time the stream has changed its direction of flow to southeast, till it reaches Kotri. Another curve round the rocky Kohistan defile in the S.S.W. direction and through a more or less defined channel, fed by a single hill torrent, the Baran, brings it down to Tatta, below which it is split up into several branches, small and large, forming the delta.

*The Deltaic Stage.*—At Tatta, the river can be said to have entered the delta proper, though in recent geological times the mouth of the Indus could be placed somewhere near Hyderabad. All that land below this old capital of Sind is a reclaimed area from the sea. Tide waters reach Tatta sometimes even now, though the sea is about 60 miles away. Devoid of any hard rocks like the Sind Tertiaries, and largely covered with alluvium, sand-hills and bars, mangrove swamps, etc., this area is quite unihabitable. The coast-line also presents a chain of tidal creeks and scalloped inlets, which get quickly silted up.

So great is the force of the inundation that it is not possible to have any ports on the actual coast, but they are situated well inland, about 20 to 30 miles distant from the sea, on one of the side branches.

Now advancing southwards and now southwestwards in the track of the S.W. monsoon, the river finally merges into the waters of the Arabian

Sea, though not without a second turbulent period of giratory streams and violent swells near the coast. Its famished condition in Sind coupled with the fact that the river has, long since, reached its highest stage of aggradation, is responsible, without doubt, for its present state of alluviation.

*Outlets and Effluxes.*—The present outlets of the Indus on the left bank are (1) the Fuleli on the east of Hyderabad and further down called the Guni, the Pharan and the Kori and (2) the Pinjari, east of Jerruck, and, later on, called the Gungra and the Sir.

The present effluxes are the Ochito and the Haidari. The following are the 13 mouths or creeks discernible in modern times :—Sir, Pakhar, Kajhar, Kharak, Kahr, Kalandri, Turshian, Hajamro, Sisa, Dubbo, Pitiani, Khudi and Pitai.

Thus, the whole river, as it exists to-day, has a long and chequered career of about 1,800 miles, through varying topography and valley stages. (See Plate 13.)

### III. The Regimen of the Indus.

The periodic floods of the river are the most important phenomenon of the Indus regimen. They are looked upon by the people, from times immemorial, as events of great moment to the province.

Upon these annual swellings and inundations, the prosperity of their fields depends. Had these inundations been regular, uniform and universal in the whole Basin, the stability of the fields would have been assured. But the vagaries of the Indus are great. Once it takes to a bank, the left or the right, it sticks to it for some time. Then it changes its direction. At times it also changes its bed and effluxes, and brings different fields successively under its sway. Also the inundation is not always general but partial. The whole area is not submerged but only portions are flooded at a time. The result is an irregular distribution of waters in the region year by year.

In a single year, again, the quantity of water also fluctuates. In the cold season the river dwindles down into an exceedingly shallow stream, the Bukkur gauge reading as low as $-2 \cdot 40$ feet at times.[10] By March and April the snows on the Himalayan heights begin to smelt and the stream is refreshed to some extent. After a temporary fall for about two months, again the river becomes fuller and fuller, till the inundation reaches its climax usually in August, when most of the snows have melted away and the lower ranges of the mountains have also received their share of the monsoon precipitation. More than the silt brought down by the current, the waters of the river are themselves valuable, so that when a second and more powerful monsoon wave comes on during the season, not only the soil gets enriched with silt but the parched land and dust of the desert also are enlivened.

These flood waters inundate the neighbouring alluvial plains and fill all the canals, distant and near.

Thus like all great rivers, especially fed by snows as well as rains, the Indus has great variations of flow from year to year and month to month. At times the waters do not rise till the beginning of April and the great flood does not come on till September. In some years the Bukkur gauge does not show a reading higher than 12·7, while in other years, there is an extra-ordinary rise of 19 feet above the lowest water-level of the year. The meteo-rological conditions also exercise some influence over the river regimen. Both the snowfall and the rainfall being variable here, there is no knowing when the Indus would have a normal flood and when an abnormal one. There is, again, a wide margin between bad and good floods in Sind. The causes of this condition are to be traced backwards to the geographical position and climatic conditions of the Upper Indus region. The snow-feeding of the Indus has already been referred to. The Sutlej is another great snow-fed river rising in the Greater Himalayas and contributing its waters to the Indus. Other Punjab tributaries of the Indus are partly snow-fed but largely rain-fed.

Some of the tributaries of the Indus rise beyond the Siwalik hills of the Himalayas, which are fed regularly by the S.W. and N.E. monsoon currents. These drain the whole area within the monsoon zone and so the showers over even a portion of the Upper Indus Basin are bound to give it an impetus. At times and during cyclonic storms there is exceptional rainfall even in the Lower Basin.

For this alteration of high and low floods, we take the Bukkur gauge as the basis for discussion. It is a point on the river course conveniently fixed in a gorge and the whole flood of the river passes through it. Lower than this, the flood level rises above the general level of the country and so the plains are flooded and the bunds destroyed sometimes. The whole run-off of the rainfall within the catchment area and the melting of the snows are secured at this gauge.

Another suitable gauge for the sake of comparison is the Kotri gauge. This is also a fixed point in the river course beside the Laki Range, and the readings are quite accurate and reliable.

*Research done by the Indus River Commission.*—The observations of dis-charges, silt deposit and transportation of sediment, etc., taken by the Indian River Commission, from January 1901 onwards, at these two and other stations are of great scientific value. They give valuable information regard-ing the flow and action of the Indus waters from year to year and day to day.

*Gauge Readings.*—A reference to the graphs of these gauge readings at Bukkur (Sukkur) and Kotri[11] from year to year will show the seasonal rise and

fall of water-level. (See Plates 10 and 11.) From the extreme shallowness of the river during the months of December and January, the river takes a turn about the middle of March when the snows begin to melt on the mountains. In April the gauge level reads over + 15 feet at Bukkur, a difference of 16 feet over the winter gauge reading, and over + 20 feet at Kotri gauge—a difference of 15 feet. Then with a short pause in May and some part of June, whenever the monsoon season is delayed, the river rises steadily until it has the maximum flood level in August. Later on, the level falls rapidly until at the end of the year the gauge again reads low after some fluctuations in winter. Thus the gauge readings are affected every year at three different times (1) at the beginning of summer when the snows melt, (2) in the summer rainy season and (3) in the winter rainy season, the predominant factors being the snowfall on the Himalayas and the rains in the Punjab and Sind. (See Graphs, Plate 13.)

The following is a summary table of the annual rise of water-level at Bukkur (Sukkur) and Kotri for a period of 29 years and their averages[12] :—

*Annual Rise of Water-level in feet (Sukkur and Kotri Gauges).*

| Year | | | Sukkur | | | Kotri | | |
|---|---|---|---|---|---|---|---|---|
| | | | Max. | Min. | Rise | Max. | Min. | Rise |
| 1902 | ... | .. | 13·50 | 1·00 | 12·50 | 15·90 | 3·70 | 12·20 |
| 1903 | .. | .. | 17·10 | 1·50 | 15·60 | 19·70 | 5·40 | 14·30 |
| 1904 | .. | .. | 15·80 | 1·20 | 14·60 | 18·70 | 5·30 | 13·40 |
| 1905 | .. | .. | 16·70 | 0·50 | 16·20 | 19·10 | 5·80 | 13·30 |
| 1906 | .. | .. | 16·60 | —0·60 | 17·20 | 20·90 | 5·50 | 15·40 |
| 1907 | .. | .. | 13·70 | —2·00 | 15·70 | 19·40 | 5·00 | 14·40 |
| 1908 | .. | .. | 16·10 | —2·40 | 18·50 | 22·90 | 4·70 | 18·20 |
| 1909 | .. | .. | 14·40 | 0·50 | 13·90 | 20·80 | 4·90 | 15·90 |
| 1910 | .. | .. | 14·50 | 0·50 | 14·00 | 22·30 | 5·60 | 16·70 |
| 1911 | .. | .. | 14·00 | 1·60 | 12·40 | 20·70 | 4·70 | 16·00 |
| 1912 | .. | .. | 15·50 | 1·20 | 14·30 | 21·70 | 4·60 | 19·10 |
| 1913 | .. | .. | 15·00 | 0·70 | 14·30 | 20·90 | 5·00 | 15·90 |
| 1914 | .. | .. | 17·40 | 1·50 | 15·90 | 23·80 | 7·40 | 16·40 |
| 1915 | .. | .. | 12·70 | —1·00 | 13·70 | 19·80 | 5·70 | 14·10 |

| Year | Sukkur | | | Kotri | | |
|------|--------|--------|--------|--------|--------|--------|
|      | Max.   | Min.   | Rise   | Max.   | Min.   | Rise   |
| 1916 .. .. | 13·60 | —0·70 | 14·30 | 22·10 | 4·40 | 17·70 |
| 1917 .. .. | 15·80 | —0·30 | 15·10 | 23·00 | 4·90 | 18·10 |
| 1918 .. .. | 11·80 | —0·20 | 12·00 | 19·50 | 5·80 | 13·70 |
| 1919 .. .. | 14·70 | 0·80 | 13·90 | 22·40 | 6·30 | 16·10 |
| 1920 .. .. | 15·00 | —0·50 | 15·50 | 21·40 | 3·90 | 17·50 |
| 1921 .. .. | 16·80 | 0·00 | 16·80 | 22·10 | 6·10 | 16·10 |
| 1922 .. .. | 15·50 | 1·20 | 14·30 | 20·40 | 6·70 | 13·70 |
| 1923 .. .. | 14·10 | 0·40 | 13·70 | 21·90 | 5·90 | 16·00 |
| 1924 .. .. | 16·60 | —1·50 | 18·10 | 23·60 | 6·00 | 17·60 |
| 1925 .. .. | 15·70 | —2·10 | 17·80 | 22·10 | 5·00 | 17·10 |
| 1926 .. .. | 15·30 | —2·10 | 17·40 | 22·70 | 5·00 | 17·20 |
| 1927 .. .. | 15·30 | —2·10 | 17·40 | 21·50 | 4·84 | 16·66 |
| 1928 .. .. | 14·20 | —2·00 | 16·20 | 19·30 | 5·52 | 13·78 |
| 1929 .. .. | 17·70 | —1·30 | 19·00 | 24·10 | 7·00 | 17·10 |
| 1930 .. .. | 16·90 | —0·30 | 17·20 | 23·10 | 6·40 | 16·70 |
| *Mean Max.* .. | 15·24 |  |  | 20·88 |  |  |
| *Highest rise* .. | 17·70 | (1929) |  | 24·10 | (1929) |  |
| *Lowest rise* .. | 11·80 | (1918) |  | 18·70 | (1904) |  |

Out of 29 years, 11 were those of low floods as can be seen from the maximum rise of water-level at the Sukkur gauge year by year, the average maximum reading there being 15·24 feet. At the Kotri guage the readings fell below the normal for 10 years, the average maximum reading being 20·88 feet. The year 1929 was an year of exceptionally heavy inundation, following one of very low floods. (See Graphs, Plate 13.)

*The River Discharge.*—The following is another interesting summary table[13] of the discharge observations of the Indus at Bukkur (Sukkur) and at Kotri compared with the annual rainfall in the localities for 20 years.

## Discharge Observations of the Indus at Sukkur.

| Year | Min. (For the year) | Max. | Width of water surface ft. | Mean vel. per sec. | Cubic ft. discharge per sec. | Wind direction | Wind vel. ft. per sec. | Rainfall |
|---|---|---|---|---|---|---|---|---|
| 1911 | 0·6 (Jan. 4) | 14·0 (Jan. 22) | 2,615<br>3,407 | 2·77<br>9·30 | 39,907<br>582,742 | N<br>S | Slight<br>,, | 0·80 |
| 1912 | 1·6 (Mar. 30) | 15·5 (Aug. 10) | 3,332<br>3,437 | 2·23<br>8·44 | 35,311<br>715,138 | ..<br>.. | ..<br>Calm | 4·73 |
| 1913 | 1·2 (Feb. 22) | 14·7 (Aug. 16) | 3,345<br>3,411 | 1·64<br>7·99 | 23,759<br>616,991 | ..<br>E | ,,<br>9 | 3·19 |
| 1914 | 0·7 (Feb. 11) | 17·3 (Aug. 5) | 3,359<br>3,434 | 1·43<br>8·96 | 23,719<br>885,165 | ..<br>.. | Calm<br>,, | 3·38 |
| 1915 | 1·6 (Feb. 13) | 12·4 (Aug. 25) | 2,841<br>3,405 | 2·29<br>8·24 | 41,703<br>430,445 | N<br>E | 3<br>3 | 1·44 |
| 1916 | —1·0 (Mar. 18) | 13·6 (Aug. 16) | 3,337<br>3,410 | 1·87<br>10·61 | 25,559<br>735,348 | N<br>.. | 6<br>Calm | 1·31 |
| 1917 | —0·7 (Apr. 4) | 15·8 (Aug. 18) | 3,332<br>3,419 | 2·42<br>9·04 | 17,568<br>740,279 | ..<br>S | ,,<br>3 | 7·46 |
| 1918 | —0·3 (Mar. 9) | 11·8 (Jun. 19) | 3,315<br>3,404 | 2·53<br>9·22 | 28,083<br>513,105 | ..<br>SE | Calm<br>8 | 0·76 |
| 1919 | —0·1 (Jan. 25) | 14·7 (Aug. 16) | 3,391<br>3,465 | 1·44<br>6·69 | 23,705<br>506,352 | ..<br>SE | Calm<br>5 | 2·84 |
| 1920 | 1·0 (Jan. 24) | 15·0 (Aug. 14) | 3,394<br>3,463 | 1·95<br>7·64 | 31,572<br>612,379 | ..<br>E | 2<br>2 | 1·37 |
| 1921 | —0·5 (Mar. 22) | 16·8 (Aug. 10) | 3,354<br>3,469 | 1·77<br>6·92 | 24,092<br>535,746 | NW<br>SE | 6<br>2 | 1·81 |
| 1922 | —0·4 (Feb. 12) | 15·4 (July 1) | 3,380<br>3,465 | 2·48<br>8·68 | 36,796<br>540,793 | NE<br>NE<br>NE | 9·57 ⎫<br>7·33 ⎬<br>4·5 ⎪<br>4·27 ⎭ | ·81 |
| 1923 | 1·2 (Jan. 29) | 14·1 (Aug. 30) | 3,383<br>3,466 | 1·88<br>6·91 | 38,447<br>620,915 | ..<br>NE<br>NE | Calm<br>3·80 ⎫<br>5·27 ⎭ | 2·72 |
| 1924 | 0·4 (Feb. 10) | 16·5 (Aug. 13) | 3,281<br>3,468 | 1·85<br>6·02 | 31,565<br>683,581 | NW<br>NW<br>NW | 6·17 ⎫<br>5·27 ⎬<br>5·00 ⎪<br>4·93 ⎭ | ·48 |
| 1925 | —1·5 (Apr. 2) | 15·7 (Aug. 9) | 2,164<br>3,450 | 2·23<br>7·95 | 30,330<br>625,727 | NE<br>S | 8·72<br>7·60 | 2·93 |
| 1926 | —2·1 (Mar. 11) | 15·3 (Aug. 22) | 1,912<br>3,464 | 2·33<br>8·19 | 27,777<br>607,226 | SE<br>SW | 11·7<br>4·7 | 5·09 |
| 1927 | —2·1 (Mar. 24) | 15·3 (Aug. 19) | 3,373<br>3,462 | 1·05<br>8·32 | 25,534<br>624,683 | NW<br>SW | 13·3<br>8·5 | 0·61 |
| 1928 | —2·0 (Feb. 12) | 14·2 (Aug. 1) | 3,005<br>3,443 | 1·14<br>8·08 | 28,342<br>476,774 | NE<br>S | 17·83<br>7·60 | 1·58 |
| 1929 | —1·3 (Mar. 8) | 17·4 (Sept. 7) | 2,941<br>3,434 | 1·77<br>8·08 | 31,218<br>677,132 | ..<br>E | Calm<br>4·35 | 11·10 |
| 1930 | —0·3 (Jan. 22) | 16·9 (July 24) | 3,315<br>3,433 | 1·15<br>7·10 | 34,627<br>642,130 | SE<br>E | 4·3<br>4·30 | 0·88 |

*Discharge Observations of the Indus at Kotri.*

| Year | Min. (For the year) | Max. (For the year) | Width of water surface | Mean vel. per sec. ft. | Cubic ft. discharge per sec. | Wind direction | Wind vel. ft. per sec. | Rainfall (at Hyderabad) |
|---|---|---|---|---|---|---|---|---|
| 1911 | 5·7 (14 Jan.) | | 2,772 | 1·71 | 36,667 | N | 10 | |
| | | 20·6 (4 July) | 3,075 | 6·60 | 395,504 | W | 9 | 3·79 |
| 1912 | 4·7 (9 Apr.) | | 2,218 | 1·93 | 27,563 | ·· | Calm | |
| | | 21·7 (17 Aug.) | 3,110 | 7·65 | 445,943 | ·· | ,, | 5·39 |
| 1913 | 4·7 (1 Mar.) | | 2,668 | 2·16 | 24,198 | ·· | ,, | |
| | | 20·8 (19 Aug.) | 3,105 | 6·58 | 444,435 | ·· | ,, | 21·13 |
| 1914 | 5·0 (21 Feb.) | | 2,583 | 1·81 | 25,543 | N | 15 | |
| | | 23·8 (11 Aug.) | 2,919 | 8·16 | 612,218 | ·· | Calm | 4·09 |
| 1915 | 7·4 (13 Feb.) | | 2,715 | 1·88 | 31,358 | ·· | ,, | |
| | | 19·6 (31 Aug.) | 2,960 | 7·70 | 343,226 | ·· | ,, | 1·01 |
| 1916 | 5·7 (1 Apr.) | | 2,580 | 1·76 | 24,291 | NE | 9 | |
| | | 22·1 (24 Aug.) | 3,047 | 5·24 | 369,212 | ·· | ·· | 14·01 |
| 1917 | 4·5 (10 Apr.) | | 2,656 | 2·03 | 17,353 | SW | 18 to 22 | |
| | | 22·8 (8 Sep.) | 3,143 | 7·51 | 609,331 | S | 5 to 7 | 9·81 |
| 1918 | 5·1 (19 Mar.) | | 2,677 | 1·11 | 21,688 | SW | 3 | |
| | | 17·0 (7 Sep.) | 2,836 | 7·42 | 306,044 | NE | 7 | 1·74 |
| 1919 | 5·8 (11 Feb.) | | 2,596 | 1·64 | 24,439 | SW | 6 | |
| | | 22·3 (20 Aug.) | 3,137 | 7·16 | 667,577 | NE | 4 | 7·76 |
| 1920 | 6·4 (20 Mar.) | | 2,640 | 1·64 | 31,442 | SE | 10 | |
| | | 21·4 (13 Aug.) | 2,954 | 7·04 | 495,360 | SW | 10 | 1·70 |
| 1921 | 4·0 (29 Mar.) | | 2,680 | 1·03 | 18,067 | ·· | Calm | |
| | | 22·1 (28 Aug.) | 3,110 | 7·25 | 520,119 | NW | 15 | 13·78 |
| 1922 | 6·1 (13 Feb.) | | 2,576 | 2·16 | 35,706 | NE | 6 | |
| | | 20·4 (10 Aug.) | 3,047 | 6·93 | 389,849 | NW | 21·5 | 2·66 |
| 1923 | 6·7 (3 Feb.) | | 2,710 | 1·78 | 37,488 | NE | 4·4 | |
| | | 21·99 (6 Sep.) | 3,081 | 6·88 | 483,559 | NW | 16·5 | 5·21 |
| 1924 | 5·90 (14 Feb.) | | 2,649 | 1·61 | 30,020 | NE | 7·0 | |
| | | 23·63 (20 Aug.) | 3,145 | 6·80 | 532,383 | NW | 23 | 12·07 |
| 1925 | 5·96 (7 Apr.) | | 2,666 | 1·51 | 30,171 | NW | 7 | |
| | | 22·03 (21 Aug.) | 3,059 | 7·22 | 442,903 | NW | 21·2 | 1·02 |
| 1926 | 5·00 (22 Mar.) | | 2,640 | 1·16 | 23,710 | ·· | Calm | |
| | | 22·70 (6 Sep.) | 3,100 | 6·30 | 411,302 | SE | 10·2 | 12·11 |
| 1927 | 4·84 (27 Mar.) | | 2,449 | 1·13 | 24,016 | NW | 12 | |
| | | 21·50 (25 Aug.) | 3,050 | 4·83 | 406,626 | SW | 10· | 13·55 |
| 1928 | 5·52 (15 Feb.) | | 2,444 | 1·41 | 26,736 | ·· | Calm | |
| | | 19·30 (7 Aug.) | 2,740 | 7·17 | 306,311 | NW | 15·2 | 2·14 |
| 1929 | 6·92 (18 Mar.) | | 2,516 | 1·45 | 29,286 | NW | 12·3 | |
| | | 24·10 (13 Sep.) | 3,178 | 6·48 | 506,082 | W | 10·4 | 23·13 |
| 1930 | 6·30 (6 Mar.) | | 2,324 | 1·34 | 34,005 | ·· | Calm | |
| | | 22·88 (30 July) | 3,159 | 6·72 | 425,192 | W | 18·00 | 2·77 |

*Factors of Discharge.*—It is clear from the above observations that the discharge varies greatly from year to year and that, at neither of the two places does it correspond with its rainfall for a particular year, proving thereby that snow-melting and rainfall in the upper regions are big factors of the total quantity of water entering. The additions from rainfall in Sind are quite negligible. For example, the maximum rainfall of 11·10 inches at Sukkur for 1929 did not show the maximum discharge at the gauge, but on the contrary 108,033 cusecs less than that of the maximum which was in 1914, when the rainfall was only 3·38 inches. Again, while in 1924, the rainfall was the least, *viz.,* ·48 inches, the discharge was 683,581 cusecs, that is, 253,136 cusecs more than that of the minimum which was in 1915, when the rainfall was 1·44 inches. So also at Kotri, the maximum discharge was 532,383 cusecs in 1924, when the rainfall was only 12·07 inches, that is, 26,301 cusecs less than in 1929, when the rainfall was the heaviest, *viz.,* 23·13 inches. Only sometimes the Baran below Kotri adds a good discharge to the Indus.

In this respect, the Indus differs greatly from the Nile River which is mainly rain-fed. Ordinary meteorological conditions do not affect our river so greatly as the Nile, where it is possible to predict high or low floods to a certain extent. (This comparison is given later. See pp. 349-351.)

A diminution of measurable discharge at Kotri compared with that of Sukkur is noticed from the data given above and the reasons are :—

    (1)  Loss by evaporation.

    (2)  Draw-off by canals.

    (3)  Loss by percolation.

*Supplies of Water Available for Irrigation in Sind.*[13]

Average daily discharge in each month in cusecs.

| Name of Guaging Station | May 1932 | June 1932 | July 1932 | August 1932 | September 1932 | October 1932 |
|---|---|---|---|---|---|---|
| 1. Mithankote below the junction of the Chenab with the Indus .. .. | 81,547 | .. | .. | .. | .. | 61,289 |
| 2. Sukkur .. .. | 61,134 | 176,133 | 276,446 | 483,622 | 180,587 | 53,636 |
| Difference .. | —20,413 | .. | .. | .. | .. | —7,653 |

| Name of Guaging Station | November 1932 | December 1932 | January 1933 | February 1933 | March 1933 | April 1933 |
|---|---|---|---|---|---|---|
| 1. Mithankote below the junction of the Chenab with the Indus | 35,177 | 28,107 | 25,382 | 23,903 | 30,641 | 60,562 |
| 2. Sukkur | 28,973 | 21,528 | 21,104 | 16,809 | 23,010 | 53,251 |
| Difference | —6,204 | —6,579 | —4,278 | —7,094 | —7,631 | —7,311 |

In the above figures for Sukkur, no allowance has been made for ' Lag,' and withdrawals *en-route* from Mithankote to Sukkur. The difference gives an idea of the quantity of water available for irrigation in Sind.

*Differentiation of Waters.*—The average daily discharge at Sukkur-Bukkur alone in each month is as under[14] :—

|  | 1927 | 1928 | 1929 | 1930 | Average |
|---|---|---|---|---|---|
| January | | 30,933 | 35,948 | 39,283 | 35,388 |
| February | | 34,766 | 36,553 | 44,759 | 38,692 |
| March | | 49,956 | 34,841 | 61,398 | 48,731 |
| April | | 92,977 | 57,926 | 158,668 | 103,190 |
| May | | 175,269 | 89,426 | 199,467 | 153,720 |
| June | 137,348 | 305,698 | 190,544 | 248,532 | 220,530 |
| July | 318,738 | 358,132 | 254,929 | 523,693 | 363,873 |
| August | 469,388 | 333,818 | 494,736 | 434,599 | 433,135 |
| September | 210,473 | 260,662 | 354,768 | 209,607 | 256,377 |
| October | 65,463 | 68,746 | 85,210 | 72,388 | 72,951 |
| November | 41,505 | 43,962 | 50,696 | 47,388 | 45,637 |
| December | 32,679 | 45,683 | 39,082 | 35,591 | 39,258 |

The maximum discharge is in July or August in alternate years, but the minimum may be in December, January or February-March. The average figures show a gradual rise from January to August and a quick fall from August to December.

How much of the flood waters is due to snows and how much due to rainfall, it is difficult to decide at present, the records being not complete. But for the sake of comparison, the following table of Discharge Observations at Punjnad, a station above the confluence of the five rivers entering the Indus has been given. Even these figures include the waters of the Sutlej, which is, as has been stated above, also a partially snow-fed river. It is, therefore, impossible to eliminate altogether the Punjab rivers' share.

*Discharge Observations of the Indus at Punjnad (Daka).*

| Year | Gauge | | Width of surface | Mean vel. per sec. | Discharge per sec. | Wind direction | Wind velocity |
|------|-------|-------|------|------|------|------|------|
| | Minimum | Maximum | | | | | |
| 1929 | 0·82 (16 Jan.) | 13·80 (28 Aug.) | 1,179 | 0·43 | 6,166 | E | Slight |
| | | | 1,996 | 6·04 | 157,882 | ·· | Calm |
| 1930 | 1·82 (10 Jan.) | 11·21 (23 Jan.) | 1,335 | 0·41 | 5,360 | NE | 7·83 |
| | | | 1,928 | 4·22 | 101,121 | S | 12·30 |

It is.to be noted that while the waters derived from the melting of the snows come down *gradually*, those of the monsoon rains descend suddenly and cause anxiety about breaches of *bunds* and destruction of the country-side by floods.

*Silt Deposits.*

*Quantity of Water and Total Volume of Silt passed down the Indus since 1902.*[15]

| Year | Sukkur | | | Kotri | | |
|------|------|------|------|------|------|------|
| | Discharge in mill. cub. ft. | Silt in mill. cub. ft. | Average silt in grains p' cub. ft. | Discharge in mill. cub. ft. | Silt in mill. cub. ft. | Average silt in grains p' cub. ft. |
| 1902 | 3,644,438 | 6,705 | 1,223 | 3,199,392 | 6,409 | 1,327 |
| 1903 | 5,079,992 | 10,441 | 1,365 | 4,271,974 | 9,980 | 1,554 |
| 1904 | 4,425,321 | 7,868 | 1,182 | 3,675,802 | 7,810 | 1,413 |
| 1905 | 5,267,580 | 9,906 | 1,256 | 4,590,679 | 9,485 | 1,386 |
| 1906 | 4,891,018 | 11,909 | 1,619 | 4,577,213 | 10,877 | 1,580 |
| 1907 | 4,304,634 | 7,348 | 1,135 | 3,979,757 | 7,515 | 1,256 |
| 1908 | 5,937,154 | 11,833 | 1,325 | 4,991,419 | 9,042 | 1,205 |

| Year | Sukkur | | | Kotri | | |
|---|---|---|---|---|---|---|
| | Discharge in mill. cub. ft. | Silt in mill. cub. ft. | Average silt in grains p' cub ft. | Discharge in mill. cub. ft. | Silt in mill. cub. ft. | Average silt in grains p' cub. ft. |
| 1909 | 5,764,731 | 13,108 | 1,512 | 4,595,008 | 9,359 | 1,355 |
| 1910 | 6,043,421 | 14,868 | 1,636 | 4,885,747 | 9,226 | 1,256 |
| 1911 | 6,192,202 | 14,652 | 1,574 | 5,321,376 | 11,869 | 1,483 |
| 1912 | 5,523,416 | 12,952 | 1,560 | 3,769,027 | 6,839 | 1,207 |
| 1913 | 4,560,365 | 8,288 | 1,209 | 3,688,071 | 6,691 | 1,206 |
| 1914 | 6,898,522 | 13,364 | 1,287 | 5,628,614 | 12,321 | 1,456 |
| 1915 | 5,608,483 | 10,452 | 1,240 | 4,709,750 | 10,790 | 1,523 |
| 1916 | 5,105,462 | 9,443 | 1,233 | 3,383,942 | 6,892 | 1,354 |
| 1917 | 5,495,731 | 12,869 | 1,557 | 4,999,969 | 12,074 | 1,606 |
| 1918 | 5,032,370 | 9,476 | 1,252 | 4,114,614 | 9,871 | 1,595 |
| 1919 | 4,767,032 | 7,388 | 1,030 | 4,835,256 | 9,970 | 1,370 |
| 1920 | 4,607,021 | 8,412 | 1,217 | 3,835,295 | 7,934 | 1,378 |
| 1921 | 4,275,002 | 7,810 | 1,216 | 4,079,895 | 8,073 | 1,317 |
| 1922 | 5,621,545 | 10,184 | 1,227 | 5,005,065 | 11,540 | 1,546 |
| 1923 | 5,124,903 | 10,036 | 1,308 | 4,745,340 | 9,951 | 1,399 |
| 1924 | 5,523,549 | 9,699 | 1,169 | 4,825,926 | 9,244 | 1,277 |
| 1925 | 4,658,859 | 8,404 | 1,179 | 3,904,341 | 8,051 | 1,378 |
| 1926 | 4,548,160 | 7,904 | 1,301 | 3,693,549 | 6,431 | 1,165 |
| 1927 | 3,928,704 | 6,445 | 1,091 | 3,184,593 | 5,054 | 1,060 |
| 1928 | 4,755,962 | 8,517 | 1,192 | 3,830,114 | 7,383 | 1,289 |
| 1929 | 4,553,355 | 8,691 | 1,276 | 3,831,745 | 6,432 | 1,130 |
| 1930 | 5,188,910 | 9,210 | 1,180 | 4,362,013 | 8,440 | 1,293 |
| TOTAL .. | 147,327,842 | 288,182 | 37,545 | 124,516,486 | 255,550 | 39,364 |
| MEAN .. | 5,080,270 | 9,937 | 1,295 | 4,293,672 | 8,299 | 1,357 |

*Observations.*—It will be seen that while, on an average, the waters at Kotri are more silt-laden than those at Sukkur, the total volume of silt carried down below Kotri is smaller than that carried down below Sukkur. The difference represents the deposit of silt on river-side banks and fields irrigated by all canals. The silt thus lost between Sukkur and Kotri during the 29 years amounts to about thirty-five thousand million cubic feet, which is equivalent to about 1,300 square mile-feet. The volume of silt passing below Kotri in 30 years is about 9,100 square mile-feet. An analysis of the silt carried shows almost equal parts of sand and silt. The following are other observations made by the Commission[16] on silt deposits :—

" The minimum amount of suspended matter is carried near the surface and the maximum amount near the bed of the river. Any variations from the general rule are probably due to disturbances, such as upward currents, eddies, etc. Strong winds also are an external cause affecting the result as they blow sand into the river. Generally the amount of silt varies with the stage of the river ; the higher the gauge reading, the greater is the silt in suspension. The noticeable features are the large increase in the quantity of silt when the river rises suddenly and the large decrease thereof when it falls quickly. The quantity of silt carried by the Indus increases with fair regularity from May 1 when the river commences to rise, up to the middle or end of September, when the river begins to fall ; thereafter the amount of silt in suspension diminishes approximately, as the discharge decreases."

*Variations in the Silt Deposits.*

| | Maximum quantity of silt recorded | | |
| --- | --- | --- | --- |
| | Max. quantity in grains per c. ft. | Date | Remarks |
| Sukkur .. .. | 3,000 | 10 Aug. 1907 | River rising |
| Kotri .. .. | 3,170 | 22 Jan. 1906 | ,, ,, |
| Dera Gazi Khan .. | 940 | 17 Jan. 1908 19 Jan. 1910 | ,, ,, ,, ,, |

*Maximum Quantity of Silt Recorded.*

| | | | |
| --- | --- | --- | --- |
| Sukkur .. .. | 50 | 1 Dec. 1906 | River falling |
| Kotri .. .. | 110 | 16 Jan. 1908 | ,, ,, |
| Dera Gazi Khan .. | 20 | 28 Feb. 1908 | ,, ,, |

The maximum quantity is when the river rises and the minimum when it falls. Also the silt is less at Sukkur than at Kotri.

Sir John Ottley, Inspector-General of Irrigation, has drawn the following conclusions :—

(1) The quantity of silt increases according to the depth below the surface.

(2) There is more silt in a rising flood than in a falling one.

(3) The maximum amount of silt is carried when the flood has reached $\frac{2}{3}$ of its height.

The observations on the Indus have been corroborated by the Commission.

*Effects of Silting.*—This variation in the discharge of waters between high and low flood seasons and the amount of silt carried during the year produce great effects on the Indus channel. They change its momentum, which in its turn causes bar crossings, spills leading to cut-offs and the consequent instability of the river regimen. The silt deposited being very fine, the bed and sides of the channel yeild to flood attacks. The result is that the gradient, depth, velocity and the course also change, the bed level rises, the meanders increase and the course of the river is lengthened. Old land is cut away first on one bank and then on the other and new land is formed on the opposite bank and so the tortuousness grows, though there is a limit to this between the higher and lower level and the low riverain tracts.

At the same time the great advance of the rich silt deposits of the river during its passage through Sind is that the soil is periodically renewed in its upper layers. The silt covering the fields makes excellent soil, requiring little tilling and manuring, and crops are grown regularly every season. After the harvest time, as the waters rise again next season, the soil gets renewed and becomes fresh for cultivation once more.

*Need of a Barrage in Sind justified.*—A river with such irregularities of discharge of water, uncertainties of flood seasons, regimen and silt deposits, and hydrographical changes would never make the irrigation system in the region a steady success. Irrigation could only be done by inundation canals, during the flood season and by lifting water from wells, etc., during the winter season. There was a great wastage of water in the monsoon season and a barrage across the river at a most convenient point, where the bed of the river was more or less fixed, was an absolute necessity. But even the safety of such a barrage would be in danger, if the physics of the river is not well understood.

## IV.  *Changes in the Course of the River.*

Such a complicated channel of waters with such varying velocities, silt deposits, etc., as the Indus must, therefore, have its bed, in the valley of Sind changed at different times.  Any appreciable stretch of land covered over with coarse gravel, called the Khaddar, on a level higher than the surrounding country is a sure indication of an abandoned river course.  The following are some of the evidences of old beds of the Indus :—

(1)  The submerged ridges and gully in the Arabian Sea, discovered by the John Murray Expedition of 1933–34, point to a course of the river, in recent geological times, not wholly identical with that in existence at present.

(2)  There being very few solid rocks in the lower part of the valley itself, there are no landmarks such as deserted gorges left by the river.  But the old gorge at Aror, 4 miles east of Rohri, is a distinct proof of at least a portion of the Indus having flowed eastwards,  beside the ruined city of the ancient Hindu kingdom of Sind.  This shows that even through solid rocks the Indus can break through on occasions.

(3)  Among other less durable landmarks may be mentioned the ruined cities of Mohen-jo-Daro, Bahmanabad, Debal, Patala, etc., some of which are even hard to trace in the alluvium, under which they have been buried. But it is certain that such cities could never have existed without a constant source of water-supply as from a large river in the absence of sufficient rainfall. Old abandoned water channels, such as Dhoroes, have been traced near them even at this late date.

*Westering Tendency.*—That there is a distinct westering tendency of the Indus in Sind *at present* is shown by the numerous Dhoroes found  in the Eastern Valley section.  According to Parker's observation, in the Northern Hemisphere rivers flowing to the north attack the east bank and those running to the south the west bank (*i.e.*) the right bank.[17]  The same effect may also be due to the rotation of the earth but here the assumption that the water of the river does not acquire the same rotatory motion as does the land, is unwarranted.  Besides it is not in all times that the Indus has westered.

(4)  This present westering tendency, however, has been clearly marked in the now starved stream of the Fuleli and the flow of the Indus on the west of Hyderabad from about the year 1758 A.D.[18]

Except Bukkur-Sukkur and Kotri, there are but few other points in the course of the Indus in Sind, which may be considered to be fixed.  Beyond Sehvan, the river can no longer ' wester ' now, due to  the higher levels of Kohistan.  But there is, so to say, not an inch of ground in other parts, which at one time or another has not been watered by the river.  Old beds and forsaken channels are common features of the region.

(5) The S.S.W. trend of the Indus delta is another important evidence to show the shifting nature of the river, even in its deltaic stage. An examination of the maps prepared by Carless, Wood, Mac Murdo, Haig and others[19] distinctly shows that the delta has been growing more towards the S.S.-W. direction and more and more outlets of the river open out here in a network of so many tidal creeks of varying shape and situation. Many collateral branches of the Indus have appeared at one time and disappeared at another.

*Causes of the Changing Hydrography.*—(1) We have already stated that the Indus in its Lower Valley stage is an aggrading river and silting is a very common every-day occurrence. Such a river with its actual bed on a level several feet higher than the surrounding country is bound to wander about and seek fresh channels every season. A reference to the charts of the river channel prepared year by year and published in the Indus Commission Records will clearly show the varying nature of the river bed within its own banks. In no two seasons is the river channel in some reaches marked the same. (See Plate 14.)

(2) The friable nature of the soil is another cause. Large masses of it are displaced and dragged away by the stream in the flood season. More than the fine silt and clay, the shifting (blown) sands and sandy clays help it greatly to fluctuate. At times a whole channel is silted up and a fresh one formed.

(3) The periodic floods and inundations with the consequent breaches of bunds also are another cause.

(4) The fall of the country to the south is only a few inches per mile. This makes the region virtually flat and the river could not be confined to one definite bed in it without marginal ' *bunds* '.

(5) It is also argued that seismic disturbances play some part in changing the beds of a river. The Aror and Bahmanabad catastrophes are ascribed to an earthquake by historians of Sind. But geologically it is open to doubt whether earthquake shocks are capable of diverting the entire course of a river, though locally they affect it to some extent.

(6) The continuous growth of the delta may have something to do with a change in the hydrography of Sind. Tatta, miles from the shore line and till recently the apex of the delta, was left in the background about 150 years ago. The Ren was dried up in 1757 A.D. The branch of the Indus, north of Tatta to Gharo, was closed in about 1826 A.D. The whole distance of about 150 miles from Gizri to Gharo is all scalloped with inlets of the sea, which once before were outlets of the great river. The principal

channel of egress about the year 1809 was the Bagar, in 1831 it was the Satar, while to-day it is the Haidari.

(7) Lastly, a change in the hydrography of the Punjab[20] must affect the river in the lower levels.    There is no doubt that some of the Punjab rivers (*e.g.*) the Ravi, the Bias and the Sutlej have changed their courses even in historic times.    The Indus, draining all of them even before it reaches Sind, is constantly disturbed by them.    Multan, Uchh, Harappa and other old towns have been thrown, within recent times, out of the influence of the Punjab rivers.    The drying up of the Saraswati-Hakra-Gagger river system has definitely affected the natural drainage in Sind.

Thus the Indus[21] has been in constant danger of leaving its bed sometime, except, of course, at present the fixed pcints mentioned above (*e.g.*) Sukkur-Bukkur and Kotri.    Even to-day with the approach of the monsoon season, the river causes some anxiety to the Public Works Department, when it shows signs of pressing towards one bank or the other.    This is especially to be watched in the region a little above the Bukkur gorge.

Such an event has already taken place in the past at Aror about the year 962 A.D. and a very good physiographical explanation of it has been given by R. D. Oldham.

" In former times the Indus wandered over the plains which surrounded the Khairpur Hills raising the level of the soil on either bank till it broke away in the low ground on one side or the other and so by degrees raising the level of every part ; during the latest phase of this process previous to the origin of the existing conditions, it flowed east of its present course and having raised the level of the ground there wandered away westwards ; by this time the surface of the alluvium had been raised till it was level with a gap in the Khairpur Hills at Rohri and as the alluvium south of the ridge would probably be at a considerably lower level than on the north side, the waters of the Indus having once found an outlet through this gap, would soon establish a permanent course for themselves.    If then we assume that the other river (the Hakra) instead of depositing silt and raising the level of its alluvium was an eroding stream, we may suppose that it gradually worked westwards till it reached the present situation of the Eastern Nara and excavated that channel ; the flood waters from the Indus would smooth off the slope between them, and had the process continued, there can be little doubt that the Indus would soon have broken away into this low-lying channel, had not the other river (the Hakra), owing to a change of course in its upper reaches dried up before this happened."[22]

*An Indirect Advantage.*—Every evil has a blessing in disguise and one great advantage of the vagaries of the Indus and its offsets is the vast area

of cultivable land, which can be irrigated along channels which were old river courses but now converted into irrigation canals. This circumstance places Sind in a unique position among the dry regions of Asia. Its potentiality from the point of agriculture is very great indeed.

### V. Physical Laws Governing the Indus.

That there are certain physical laws whereby such an alluvial river as the Indus frequently breaks through its banks and changes its bed cannot be denied. In this respect this river resembles other alluvial rivers such as the Mississipi, the Amazon, the Hoang-ho, the Ganges and the Irrawaddi in their lower reaches. An authority on this subject says :

" A main river of the class under notice might be expected to run in a more or less straight course, were it not that it is under compulsion to co-ordinate its velocity to what the materials of its bed and banks can best stand up to. But on account of the caving and other kinds of erosion made possible by the relative incoherence of the soil, the thread of the main stream lengthens itself by bending until its velocity tends to approach that at which caving and erosion will cease. *If only the discharge of a river were constant* throughout the year and in successive years, a time would doubtless arrive when bed, banks and current would have so far adjusted their difference as to arrive at *stability of regimen*. But such a state of things is rendered impossible by the periodic changes of discharge volume which are the consequence of rainfall or in India chiefly of the melting of Himalayan snows. The result of this instability of conditions is that permanency of regimen is never attained and so in the process of time the river is found occupying, in turn, each and every part of an area bounded by a certain pair of lines beyond which it never ordinarily wanders."[23]

*Molloy's Theory of the Indus.*—Mr. Molloy in his pioneer work on this subject has evolved a theory whereby he explains how the river happens to shift its bed, how to some extent this might be foretold, and how its effects may even be counteracted.

The following resume of Molloy's theory of the Physics of the Indus has been given by F. J. E. Spring, Chief Engineer, Indian State Railways :

" The extent of mischievous erosion at any given place depends on the quality of the soil of that place and on the velocity of the current. The quality of the soil is pretty much the same everywhere on the length of the Indus under consideration, that is, no where can it stand up against velocities greater than between about six and ten feet per second. But the velocity varies very greatly and local slopes varying from 1 in 2,500 to 1 in 8,000 are found not only in the low water but also in the high water season. It is

important to understand when and where steep surface slopes may be looked for, so as to be able to anticipate and perhaps to prevent their occurrence, if it should prove worth while to do so. That is, if there should be urban or irrigational interests worth the expenditure needed to prevent such occurrences. The incessant and often violent alterations in the surface slope are exceedingly perplexing; but they may almost always be traced to the action of the mid-stream bars or crossings."[24]   (See Diagrams, Plate 13.)

Thus the instability of the river bed depends upon the inequalities in the range of rise and fall of the river, variations of discharge, disturbance of momentum and action of mid-stream bars or crossings.

*Oldham's Theory.*—R. D. Oldham, formerly of the Geological Survey of India, after his investigations of the river at Dera Ghazi Khan in 1902 propounded another theory,[25] based on the four principles of M. Dausse,[26]* a French engineer:

" The Revenue Survey maps show that the Indus is alternately concentrated into a single channel and splits up into several smaller ones, that is, it presents the alternation of reach and fan. (A comparison of maps of different dates would permit of an estimate being made of the rate at which they gradually encroach on each other.)

" If in one of the ' fans,' there is or arises a solid obstacle not readily eroded by the current of the stream, it will have no effect, so long as one of the minor channels of the fan does not impinge on it. When this takes place, the current will be unable to remove the obstacle and the channel will be deepened by scour against its face, the current increases in velocity owing to the increased depth of channel and erosion be set up, which will cut backwards into the fan. Now the gradient of this channel of erosion is markedly less than that of the surface of the ' fan ' and consequently as it cuts its way back, there will be a stretch of very steep gradient and excessive erosion at

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* *Dausse's Principles:*—

(1) Every stream tends to a condition of equilibrium in which the velocity developed is just sufficient to enable the stream to transport its solid burden.

(2) A stream or a river flowing over an alluvial plain of its own making and consequently in a state of approximate equilibrium between velocity and load, does not flow in a channel of uniform section or gradient. (Every such river or stream is alternately collected into a single deep and well defined channel and spread out into a thin shallow sheet or split up into several channels.)

(3) The gradient of such a stream is not uniform. (The reaches where the stream is collected into a single deep channel will acquire a lesser gradient than where the stream is spread out over one of the intervening fans.)

(4) Both reach and fan work gradually upstream the reach encroaching by erosion on the fan above and being itself encroached on by deposition at its lower end.

—(*Memorandum on the Indus*, by R. D. Oldham, 1902, Appendix V, pp. v & vi.)

its head, the gradual deepening of the channel as it cuts back into the fan will attract more and more of the water of the stream, till it may be that the whole volume is concentrated in a single channel, thus establishing a 'reach' in the middle of what should be a 'fan'. The gradient of this 'reach' will be less than the average gradient of the stream, the slope of the fan is greater than this average and consequently there will be violent erosion taking place near the head of the reach which will rapidly cut its way upstream into the fan." (See Diagrams, Plate 13.)

*Conditions in the Lower Indus Basin.*—The conditions in Sind, especially in Upper Sind, are similar to those depicted by Oldham for the district of Dera Ghazi Khan. The formation of 'reach' and 'fan' in turn, the increase and decrease of velocity of 'current,' and the erosion of the bed and banks are generally in agreement with this theory. But there are a few local peculiarities in the flow of the Indus :—

(1) The Indus in Sind is running on ground higher than the land which is falling on either side, so much is the aggradation taking place.

(2) The cold weather discharge is the lowest in Sind.

(3) The nearer the river approaches the sea, the more are its meanders and the larger the round bends, as the following table[27] shows :—

| | Successive 100 miles length | A<br>Length<br>measured direct | B<br>Length<br>measured<br>round bends | Percentage<br>of<br>Meanders |
|---|---|---|---|---|
| 1st | 100 miles beginning at the sea | 72 | 100 | 39 |
| 2nd | Do. | 75 | 100 | 33 |
| 3rd | Do. | 72 | 100 | 39 |
| 4th | Do. | 69 | 100 | 45 |
| 5th | Do. | 82 | 100 | 22 |
| 6th | Do. | 82 | 100 | 22 |
| 7th | Do. | 93 | 100 | 7 |
| 8th | Do. | 98 | 100 | 2 |
| 9th | Do. | 97 | 100 | 3 |

As a result of this increasing tortuosity towards the delta, the river brings less and less water as it flows downwards.

(4)   The floods are heavier and so the changing conditions during the flood and the time when the river falls cause frequent cut-offs, scours, erosion of bed and banks, etc.

Low and overtopping banks, ox-bow lakes and the ultimate cutting out of the narrow neck of land with the consequent shortening of the length of the stream, excess of velocity of the current—all cause flooding of the fields and erosion of banks.

(5)   There are a few fixed points in the  whole  course  of the river through Sind.   At Sukkur there is a narrow gorge in the limestone rocks producing rapids during the time of inundation, at Kotri where hard clay beds rest against gently dipping Kirthar rocks and at Jheruck, where masses of hardened banks protect the stream.   At all other points the banks in the immediate neighbourhood of the stream are continuously undermined on the concave sides and aggraded on the convex sides of its wanderings. Thus old banks are destroyed in one season and new ones are made in the next.   At times two sets of banks are clearly noticeable, *viz.*, temporary destroyable banks a couple of miles apart and permanent ones as much as 15 miles apart.

*River-training.*—Unlike the system of river-training in the Punjàb, there are no elaborate works such as the old-spur system or the modern practice of guide banks undertaken in Sind, to confine the current of the river to a particular direction through a bridge or over a weir.   The flood menace being the chief danger here, the Zamindars in the past used to protect their land by "Bannas" or small bunds round their fields. During the British period, however, elaborate river embankments have been constructed. To protect the country from devastation by flood or the river from eroding breeches in their banks or in the canals such embankments or dykes have proved very useful. These 'bunds' are frequently strengthened or reinforced with loops after breeches made in them by the river Indus.   Even in the Eastern Nara Valley, expensive embankments have been built to retain the increased supply of water within the valley.

Some of the important *bunds*[28] are as follows :—

| Right Bank | | Length in miles | Left  Bank | | Length in miles |
|---|---|---|---|---|---|
| Kashmor Bund | .. | 73 | Naich Bund | .. | 34 |
| Sukkur Begari Bund | .. | 46·5 | Kasimpur Bunds | .. | 10·5 |
| Ghar Canals | ,, .. | 45·8 | N. Sukkur  ,, | .. | 28·25 |
| Nara Canal | ,, | 77 | Naolakhi (Bhorti) Bunds | .. | 8·92 |
| Manjhand | ,, .. | 5·75 | Fuleli Canals .  ,, | .. | 35·01 |
| Karachi Canals | ,, .. | 56 | Karachi Canals | ,, .. | 98 |
| Total miles | .. | 304·05 | Total miles | .. | 214·68 |

*Safety of the Sukkur Barrage.*—As the site chosen for the Sukkur Barrage is the safest, the river having never left the bed just below the Bukkur gorge, where it is located, there are no chances of the river bed to change and of the Barrage works to suffer. There are, however, chances for the river channel to break through the banks on the upstream side (*i.e.*) 15 to 20 miles north of Sukkur. Here the river is trying to erode the bank and to cause a breach in the protective *bund*. During the flood season of 1935 some water did actually flow down the depression along the Eastern Nara (beyond Aror) and was probably absorbed by the desert sand. The usual precaution against such breaches, *viz.*, looping the bund, is taken. On the whole, the safety of the Barrage is now assured. (See Plate 14.)

## VI. Navigability.

A discussion of the navigability of the river Indus has its greatest value probably from the point of view of commercial intercourse.

*History of Indus Navigation.*—A study of the latest archæological discoveries in Sind tends to show that there was a possible intercourse by sea between the people of the Indus Valley (Mohen-jo-Daro) and those of Sumer (Mesopotamia) by sea. Their influence had reached far inland, in India even upto the banks of the Ravi and as far as Harappa at least. No doubt, the Indo-Sumerians utilised the waterway of the Indus to their great advantage and proved its navigability even in their earliest civilisation.

The credit of directing the first geographical survey of the Indus is given to the Iranian sovereign Darius the Great, who employed his Greek engineer, Skylax for the purpose. The wealth of geographical information, gathered by the Iranians, was then utilised by Alexander the Great, who ordered his navy down the Indus river under the command of Nearchus. Himself a great lover of martial fame, he created new cities such as Patala on the banks of the rivers and on its delta. Thus the first naval power established on the Indus was his, and though his influence in the East died out soon after his death, a way for all European trade was opened by him. " The march of Alexander the Great from the Beas to the ocean with the voyage of Nearchus marks the coming line of European trade with India,"[29] and indeed, the intercourse between the East and the West was flourishing for long. " The Indus trade route was a sheer necessity, because Mahomed wrested Egypt from the Byzantine power and closed the overland route of Suez to the Greeks," and the Indus became " a new channel by which the productions of the East might be transmitted to the great emporium of the West." Again, " The rich and easily stowed products of India were carried up the great river as far as it was navigable, thence transported to the Oxus, down whose stream they proceeded as far as the Caspian Sea. There they entered

the Volga and sailing up it, were carried by land to the Tanais (the Don) which conducted them into the Euxine Sea, where ships from Constantinople waited their arrival."[30]

This movement of Indo-European commerce continued in later times. Unfortunately the dark ages of Mediæval Sind in succeeding centuries have left no historical records to show the utility of the Indus as a navigable river. Now and again, as the Indus Valley came to be ruled by a multitude of fighting chiefs particularly after the downfall of the Moghuls, the Indus was disused as a highway of commerce.[31]

But the Sindhis were a good sea-faring race. Long before the advent of the British in Sind in the thirties of the last century, the natives used their crafts. There was no dearth of native boats of various kinds used by them, such as the Dundies, Jumptis, Zorucks, etc.

*British Surveys of the Indus.*—Lord Ellenborough was among the earliest Englishmen to discover the navigability of the Indus and to press the East India Co. to utilise it for strategic purposes. He ordered an expedition under Lt. (afterwards Sir) Alexander Burnes, who thus became the first British navigator of the Indus in 1831. With the excuse of sending a present of English horses and a heavy carriage to Ranjit Singh from His Majesty George IV the British Government took an opportunity to explore the river route to the Punjab. Burnes undertook to collect data regarding " the depth of the stream, its facilities for steam navigation, the supply of fuel on its banks, and the condition of the princes and people who possess the country on it."[32]

In this project Burnes succeeded well and preparing a Memoir on the Indus together with a Map, presented the same to Lord Ellenborough. The expedition utilised the Pittee mouth of the Indus for their starting point and sailing in boats from Tatta on 12th April reached Hyderabad after six days' journey ; thence *via* Sehvan to Khairpur and Sukkur, where they halted for about a month, they reached Lahore ultimately on the 18th July. Thus the value of the Indus as a waterway was definitely proved by the British.

A scientific survey of the Indus from many points of view was soon undertaken by the British and we have to-day the following excellent reports and memoirs,[33] giving us an idea of the conditions of the Indus which were then prevalent :—

(1)  " Memoir on the River Indus," by J. F. Heddle (May 1836).

(2)  " Memoir on the Delta of the Indus," by Lieutenant T. G. Carless (September 1837).

(3) " Report upon Portions of the River Indus, surveyed in the years 1836 and 1837 " by Lieutenant T. G. Carless.

(4) " Report on the River Indus " by Lieutenant J. Wood completed in October 1838.

They give detailed information on the following important points relevant to our subject : descriptions of the collateral branches and sections of the Indus, observations on the periodical swell and the nature of the various mouths, navigation, boats of the Indus, soundings, tonnage, etc. On the navigability of the river, Heddle observes :

" The *Indus* steamer in which I embarked, reached the main stream of the river Indus, not by that embouchure by which the principal body of the water is discharged, but by the *collateral branch*, called Hujamree, which in maintaining the intercourse between the upper part of the Indus and the sea, answers the same useful purpose to navigation, in relation to that river that is served by the Hooghly in reference to the Ganges."[34]

On the navigable character of the whole river, Lt. Wood[35] has given valuable information. According to his observations the facilities afforded by the river vary with the state of the bed of the river and with the locality. Within the delta, navigability is difficult on account of the instability of the numerous channels, though there is a good depth of water in them ; the passage between the delta and Sehvan is the best. Between Sehvan and Roree or Bukkur, the depths are irregular again and higher up the river is well suited to navigation. This is restricted to some months of the year ; during the rainy months the passage is actually hazardous.

A number of cross-river soundings taken by Wood revealed a variety of depths from half a fathom to six fathoms higher up.[36]

On the whole, the depth of water in the channels throughout Sind and even higher up was sufficient for the whole year for navigation *by country crafts*. The average depth of the river, when full, was about 24 feet, and in the off-season about 9 feet. The greatest depth is recorded between Kalabagh and Attock, *viz.*, 186 feet. The average width of the river is 680 yards. The fall of the river per mile is as follows[37] :—

*Distance by the River.*

|  | 541 miles | 313 miles | 87½ miles | Unknown |  |
|---|---|---|---|---|---|
| Mouth | 6 inches per mile | 8 inches per mile | 20 inches per mile | ? | Source |

*Prevailing Winds in the River Valley.*—The prevailing winds in the valley are :—

(1)   Southerly (monsoon) for six months, from April to September.

(2)   Northerly for the remaining six months, from October to March.

These help or hinder navigation to a great extent, as the season may be. The southerly winds are very strong and reach the interior of the Punjab but grow less and less strong as they go upwards ; while the northerly winds are not so steady, but at times violent and very cold. There are occasional gales received also from the south in the hot season and marked by cloudy, rainy weather.

Besides these, there are local light breezes along the banks of the river, varying from place to place.

*Difficulties of Navigation.*—The uneven depths of the river and some of its branches within the delta, the low or high nature of the banks and their instability, the pressure influences of the tide and monsoon winds, sudden rises and depressions in the channel due to rains or desiccation and, above all, the loose and friable nature of the soil and the sand banks or mud-banks—all affect the navigability of the river to some extent.

Among other difficulties are those of finding the entrance through one collateral branch or the other, of the shallow depth of water in the cold season, and the absence of suitable ports accessible to vessels of burden. While the river is broad and sufficiently deep from Hyderabad northwards, the channel from the seaboard to Hyderabad is not so suitable.

*Present Conditions of Navigation on the River.*—The Indus has not been surveyed from the view-point of navigation in recent years. The railways, built by the N. W. R. authorities, have displaced the only available water-way in the past, though it can be developed for native crafts side by side.

The conditions of the Indus, at present, cannot be very different from those depicted above ; there is, however, no doubt that more and more silting has been taking place, making navigation more and more difficult, though not impossible, even for the high-sterned flat native boats which pass in and out of the river every year. During the winter season, however, the position is now different. The Barrage has actually created a high level of water in front of the gates—there is a difference of as much as 10 feet between the levels upstream and downstream and very little water actually passes under the gates.

## VII. *Other Characteristics of the River Indus.*

(1)   *Difference between the Left and Right Banks.*—The Indus has a comparatively shallow bed and undefined banks during the greater part of the

year.   In the season, when the level rises, silt deposits are laid layer by layer and the banks become higher and higher.   Comparatively less silt is carried into the canals on the left bank than on the right.

It is also noteworthy that while on the left bank there are several old abandoned and tortuous channels with well-defined banks, there are no such channels noticeable on the right bank.   This in the opinion of C. W. Tremenheere, who surveyed the area in 1867, is due to the enormous accumulation of deposits on the left bank and the westering tendency of the main stream.

(2)  *Floods.*—The river is well known for extraordinary floods.   These are caused by several agencies :—

(i)  Excess of snow falling on the Himalayas.

(ii)  Blocking of the stream in the uplands by glaciers, such as that of the Shyok or the Gilgit.[38]

(iii)  Cyclonic rains.

(iv)  Breaking down of the dykes, embankments or ' *bunds* ' erected along the courses of the river and the canals.

Such extraordinary floods were recorded in the years 1841 and 1858 in the past and in 1928 recently.

" From the report of the Natives, it appears that a very high inundation sometimes occurs in Sind, which invariably causes great alterations in the lower part of the Indus ;  it is said to happen once in about half a century. About eighteen years ago (1819 ?) one of these floods came down the river, rose to several feet above its usual height during the swell, and the strength of the current was much greater than in ordinary seasons ;  while villages were swept away from the banks, and in many parts of the country the crops were completely destroyed.   On this occasion, the river altered so much about the part, where the Setta was thrown off, that a larger body of water than usual was forced into that stream, and it increased in size considerably. The change became greater every successive year, until at last the main river turned into the Setta and abandoned the Buggaur altogether."[39]

(3)  *Silt carried off Keamari.*—The force of the S.W. monsoon wind is very great on the coast, so much so that the silt, brought down by the river and dropped off its mouths, is carried far and wide.   The mineral character of the muds off Keamari examined by Tremenheere[40] appeared to him to be akin to that of the silt carried by the Indus as has been already noticed. They contained quartz and mica in a finely divided state and appeared to have been brought near the harbour by the influence of the S.W. monsoon current on the sea waters.

(4) *Nature of River Banks.*—The banks gradually grow steeper as we move upwards reaching a height of about 15 feet but in the lower part of the Delta there are low banks. In places they stand steep and wall-like.

(5) *Best Bridged River.*—Owing to its peculiarities, irregularities and exceptional length across the various types of rock formations, and through alluvium, old and new, the River Indus has come to be exceptionally and peculiarly bridged (*e.g.*) between Leh and Kotri, it possesses all sorts of bridges including boat-bridges.

The position and construction of the Landsdowne Bridge of Sukkur is a triumph of Indian bridge-building. There being little space between the Bukkur island and Sukkur, a cantilever bridge was the only possibility. The Barrage with as many as 66 spans is a marvel of civil engineering. Another important bridge is at Kotri, crossing the mud banks of the river, and at the old port or Bunder of the Indus Flotilla, called Gidu.

A scheme of waterworks for Karachi with a canal from the Indus at a convenient point in Lower Sind is being prepared by the Karachi Municipality.

### VIII. *Comparison with the Nile.*

In his discussion about the variation of the Nile flood, Captain H. G. Lyons[41] suggested certain meteorological conditions extending over large areas in Asia and Africa and affecting the rainfall and floods of the Nile. The variations of atmospheric pressure and of the maximum and minimum sunspots have something to do with it, though the observations of these conditions do not guarantee any production of high or low flood pulses.

His conclusions are :—

" (1)  Generally speaking, the curve of Nile floods varies inversely as the mean barometric pressure of the summer months ; high pressure accompany low floods, and low pressure accompany high floods.

(2)  These pressure variations show a great similarity over wide areas, but seem to be to some extent dependent upon the position of the Azores high pressure 'action centre'.

(3)  Taking the monthly means of atmospheric pressure, this relation is even more clearly shown above or below the normal, in months of the rainy season of Abyssinia, coinciding closely with deficiency or excess of rainfall.

(4)  Taking the 37 years (1869–1905), in 6 years out of 7 a very fairly accurate prediction of the flood from month to month could have been made, and there seems a reasonable probability that further and more detailed study of the conditions above described may increase the reliability.

(5) The effect of excessive subequatorial rainfall in April and May in the neighbourhood of Zanzibar seems to have a distinctly prejudicial effect on Abyssinian rains."

In the same way, it is possible that whenever there is a diversion of S.W. monsoon currents from the west and northwest India to either Abyssinia or Burma, there is likelihood of general or local scarcity of rainfall in the region. At the same time a weakness of the wind currents in one area may also be felt in areas in similar latitudes, as the tropical rainfall of all these localities is " caused primarily by the transfer northward of the equatorial rainbelt followed by the northward extension of the southeast trade winds."

But as we have noticed above, mere meteorological conditions over the Indo-Gangetic plain do not affect the Indus floods in a particular year, snow-melting making a lot of difference in the discharge. There are other material differences also to be noticed between these two great rivers :—

|  *The Indus.* | *The Nile.* |
|---|---|
| 1. An antecedent river flowing across the Himalayas and a consequent channel through a synclinorium, from north to south. | 1. A consequent river now flowing through a rift valley near the source, from south to north. |
| 2. Sources of water-supply unsteady : (i) Glaciers (snow-melting in summer months), (ii) Numerous affluents, (iii) Seasonal (monsoon) rains (S.W. and N.E.). | 2. Constant water-supply. Equatorial rains (March and September) only. No snows. Seasonal rainfall (monsoon) on Abyssinian highlands (July-August). |
| 3. Variable channels. | 3. Comparatively constant channels. |
| 4. Considerable fall—11,000 feet at Gilgit. | 4. Less fall from heights. |
| 5. Light, friable, shifting soils and fine sand banks, shallow and shifting torrents. | 5. Rocky parts in upper region. Argillaceous soil, deep bed, uniform flow and rapids and cataracts, in lower region. |
| 6. A Barrage at Sukkur. | 6. A Dam at Assuan. |
| 7. No lake regulation and hence disastrous floods in season. | 7. Lake Victoria serving as a reservoir. No irregular floods. |
| 8. No tributary in Sind (Lower Valley). | 8. Tributaries of the Blue Nile and the Atbara in Egypt. |
| 9. Navigation—Only in flood seasons, though difficult due to sand banks ; small native boats sail, flat- | 9. Navigable in all seasons and times—Large boats meant for sea voyages and shore-going craft used. |

|  |  |
|---|---|
| *The Indus.* | *The Nile.* |

bottomed and light, drawing 3 feet of water merely.

10. Colour of water—muddy but capable of filtration.

11. Ever changing and growing delta and mouths of the river.

12. No great or old towns, ports; not yet a well cultivated valley.

13. Present average advance of delta 4 yards per year.

14. Climate—Extremes of heat and cold. Scanty rainfall.

15. One of the best bridged rivers in the world.

10. Blue to red due to $Fe_2O_3$ in suspension.

11. Better delta.

12. Large old towns exist. Richly cultivated valley.

13. $4\frac{1}{3}$ yards per year.

14. Hot and cold seasons. Good seasonal rainfall.

15. Not well bridged.

## IX.  *Summary of Statistics.*

| | |
|---|---|
| Total length of the River course from source to mouth  ..     ..     .. | 1,800 miles. |
| Length of the River in Sind (with windings) | 580 miles. |
| Drainage area of basin ..     ..     .. | 372,700 sq. miles. |
| Total area of Lower Indus Basin (Sind)  .. | 52,994 sq. miles. |
| Discharge (average of 29 years) at Sukkur | 5,080,270 mln. c. ft. |
| Do.          do.          at Kotri .. | 4,293,672 mln. c. ft. |
| Discharge (Minimum) ..     ..     .. | 17,568 cusecs. |
| ,,     (Maximum) ..     ..     .. | 885,165 cusecs. |
| Highest rise of water level (1929) at Sukkur | 17·70 feet. |
| ,,          ,,          at Kotri | 24·10 feet. |
| Silt carried (average for 29 years) at Sukkur | 9,937 mln. c. ft. |
| ,,          ,,          at Kotri | 8,299 mln. c. ft. |
| Average inclination of the plain     .. | 9″ per mile. |
| Maximum mean velocity per second     .. | 10·61 feet. |
| Silt carried  ..     ..     ..     .. | 1,000,000 tons a day. |
| Depth of the stream in the delta..     .. | 1 to $4\frac{1}{2}$ fathoms. |
| ,,          ,,     higher up  ..     .. | 1 to 6 fathoms. |
| Total length of irrigation canals, branches, tributaries ..     ..     ..     .. | 6,211 miles. |
| Length of the longest canal (Rohri) in the Indus System     ..     ..     .. | 208 miles. |
| Total command under all canals     .. | $7\frac{1}{2}$ million acres. |

*Summary.*

Chapter I deals with the physiography of the Lower Indus Basin (Sind) and includes the physiographic regions, classified according to the principles of physiographic division, which have proved fruitful of results in the hands of American geographers, especially with regard to the problems of water-supply, economic resources, industrial possibilities, population, etc. This has also been embodied in a map of the region on the scale of 1 : 1,000,000 and the descriptive materials for the same have been drawn from existing geological literature and geological and other survey maps and atlases of Sind, aided by personal observations in the field.

The main divisions into provinces are (I) Western Highlands, subdivided into (A) the Kirthars and (B) the Kohistan areas; (II) Lower Indus Valley, subdivided into (A) Western Valley section, (B) Eastern Valley section, and (C) the Deltaic Area; and (III) the Desert Province, subdivided into (A) the Pat and (B) the Thar. They are all differentiated from one another from the points of view of structure and erosion of rocks, redeposition of material by sub-aerial agencies, etc.

A brief history of the geology of Sind, including the growth of the delta and the evolution of the coast-line has been given and the origin of the Indus Basin discussed. The general geology and surface topography of all the regions, showing ground contour lines, sand and clay belts, *Kalar* lands and sand-hills are sufficiently dealt with and illustrated; the subsoil water-level contours and their fluctuations in the wet and dry seasons are made to indicate areas suffering from water-logging. Rivers, hill torrents or *Nais*, saline lakes or *Dhands* are also described and the drainage capacity of each division has been particularly considered.

Lastly, a review of the economic resources of the province of Sind has been taken, division by division, and their future development indicated.

·The history of the principal water-course of the land, *viz.*, the Indus River, both geological and recent, and the nature of its regimen form the subject of Chapter II. The Indus owes its origin probably to the ancient river designated the *Indobrahm*, which flowed by the foot of the Himalayas from Assam to the Potwar plains and down to Sind, in the Siwalik age. This has been also suggested by the John Murray Expedition, which explored the Indian Ocean and other waters in 1933. The Indus, being snow-fed as well as rain-fed, has a unique discharge of water, the graph showing two distinct peaks, one early in the hot season when the snows melt and the other in the monsoon season when it rains in Northern India. The silt-carrying capacity of the Indus is also gauged. So much has been the irregulatriy of discharge

from season to season and from year to year, irrespective of the meagre rainfall in Sind, that the need of the Lloyd Barrage at Sukkur is justified. That there is a distinct change in the hydrography of the region has been next pointed out and this discussion leads to the consideration of the theories of river regimen of Molloy, Dausse and R. D. Oldham, which are applicable to the Lower Indus Valley in general.

River-training, especially the protection of the countryside from destructive floods by means of ' *bunds* ', are essential in this region, as floods are a proverbial menace to the inhabitants of Sind from the earliest times, witness Mohenjo Daro. The task of protecting the safety of the Barrage is indeed great. That the river is also navigable to a certain extent is shewn from the records of ancient and modern times. Thus the Indus has been proved to be most serviceable to Sind from several vital points, though it differs in certain particulars from the Nile river and its regimen.

The paper is illustrated with appropriate maps, sketch maps, graphs, charts, etc., put together for the first time for this pioneer regional study of an Indian province.

I am indebted to Prof. E. G. R. Taylor, Dr. A. M. Mathews (both of the London University) and to Prof. D. N. Wadia, of the Geological Survey of India, for their guidance and helpful suggestions.

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DESCRIPTION OF PLATES.

1. Physical Map of Sind, showing natural relief, etc.   (Scale:   ½″ = 16 miles.)
2. Geological Map of Sind.                                                    Do.
3. Map of Sind showing Physiographic Divisions.                              Do.
4. Map of Sind, showing—                                                     Do.
    (1) Thermal Springs.
    (2) Hill Ranges and Water-Channels.
    (3) Manchar–Aral Drainage system.
    (4) The Indus and the Canal system.
5. Map showing ground contours.                                              Do.
6. Map showing hydro-isobaths, October 1933.                                 Do.
7. Map showing hydro-isobaths, April 1934.                                   Do.
8. Map showing sand and clay belts.                                          Do.
9. Map showing Kalar areas.                                                  Do.
10. Graphs showing Gauge readings and Discharge at Sukkur.
11. Graphs showing Gauge readings and Discharge at Kotri.
12. Plate showing—
    (1) General Section of the Kirthar Range.
    (2) Section at Jakhmari Peak.
    (3) General Section of the Laki Range.
    (4) Section across Laki spring.
    (5) Section across Mangho Pir spring.
    (6) The Indo-Brahm.
    (7) Keamari Harbour (recent and artificial).
    (8) Keamari Harbour (old and natural).
13. Plate showing—
    (1) Maximum yearly readings (Sukkur Gauge).
    (2) Maximum yearly readings (Kotri Gauge).
    (3) Molloy's Type river and notation (Plan and Section).
    (4) Oldham's Theory to illustrate Dausse's principles (Plan and Section).
    (5) The Indus system and the Lower Indus Basin.
14. Plate showing—
    (1) The Indus River oscillations.
    (2) The Indus Delta—hydrographical and other changes.
    (3) Structure of Asia..
    (4) Foundations of Asia.
    (5) Section across Lat. 27° 46′.
    (6) Section across Lat. 26° 30′.
15. Plate showing Subsidence of the Indus Gorge and Gondwanaland.
16. Relief Map of Sind in light and shade.
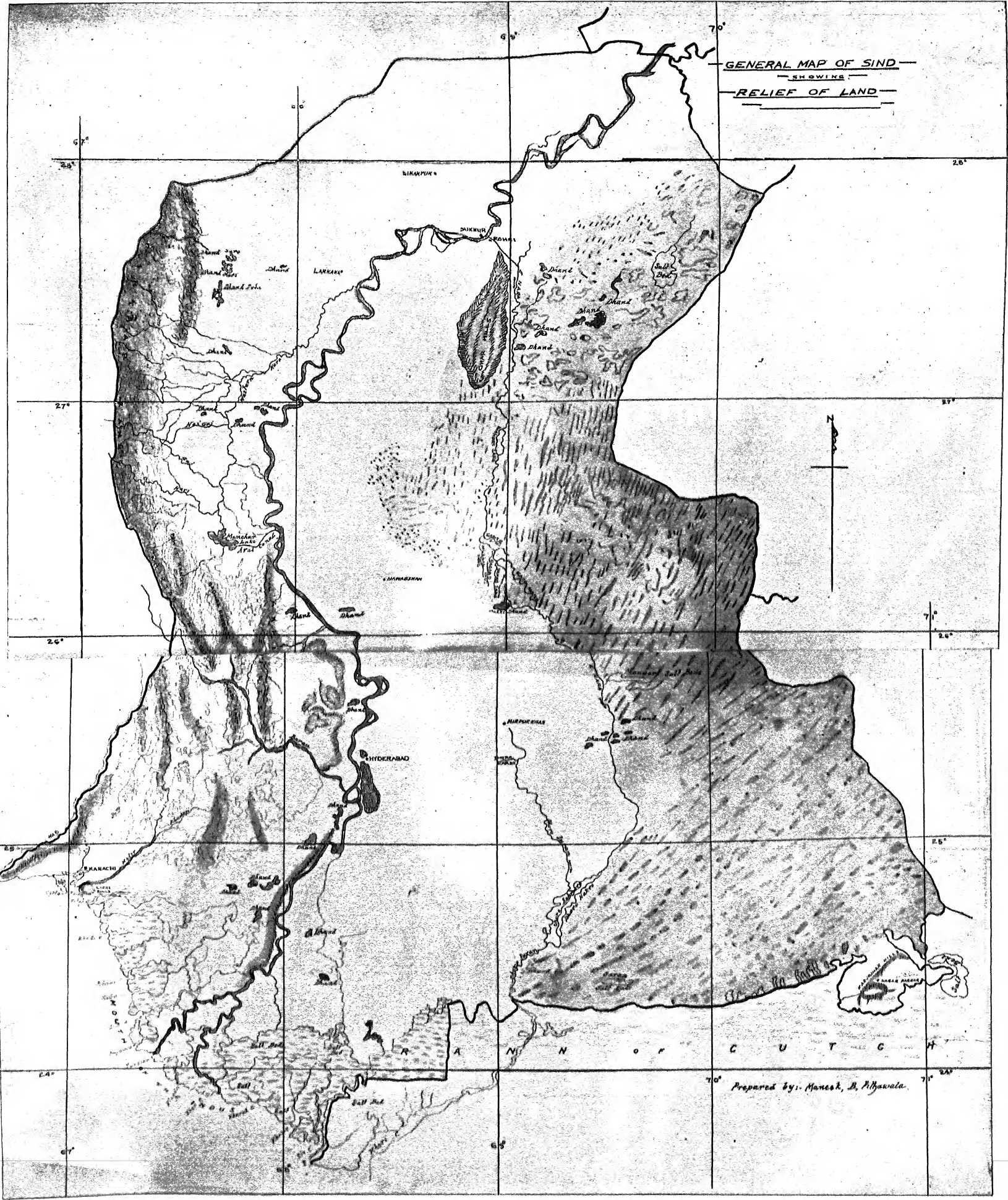
Maneck B. Pithawala.

Proc. Ind. Acad. Sci., B, vol. IV, Pl. XIX.
(PLATE 1)



GENERAL MAP OF SIND
SHOWING
RELIEF OF LAND

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Proc. Ind. Acad. Sci., B, vol. IV, Pl. XXI.

(PLATE 3)

PHYSIOGRAPHICAL DIVISIONS
— OF SIND —

REFERENCES

— DIVISIONS —

Extra Peninsular Min.
Indo Gangetic Plain

— PROVINCE —

I. Western Highlands

II. Lower Indus Valley

III. Desert Province

— SECTION —

(A) Kirthar Mt.
(B) Kohistan Section
(A) Western Valley Section
(B) Eastern Valley Section
(C) Deltaic Plain
(A) The Pat
(B) The Thar

16 MILES   N

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Proc. Ind. Acad. Sci., B, vol. IV, Pl. XXIII.

(PLATE 5)
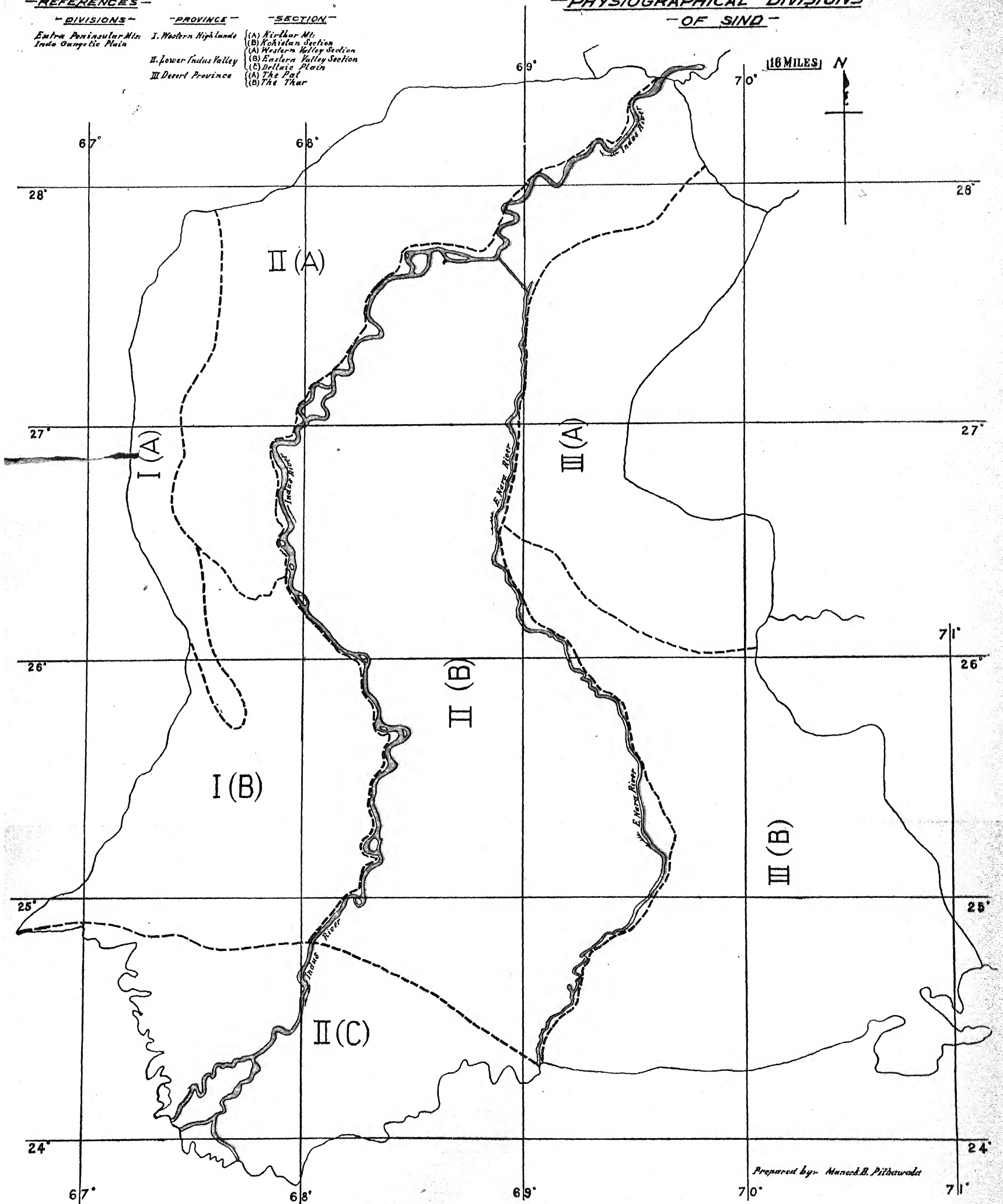
—MAP OF SIND—
—SHOWING GROUND CONTOURS—

16 Miles

— REFERENCES. —

Ground Contours

— NOTE —
1. Areas out of Barrage zone North &
   South of it, have not been surveyed
   in detail.
2. The contours in Barrage zone have
   been taken from Lloyd Barrage
   contour Survey sheets
3. The contours outside Barrage zone
   have been taken from the Survey
   Map of India published by the
   Surveyor General of India (1905)
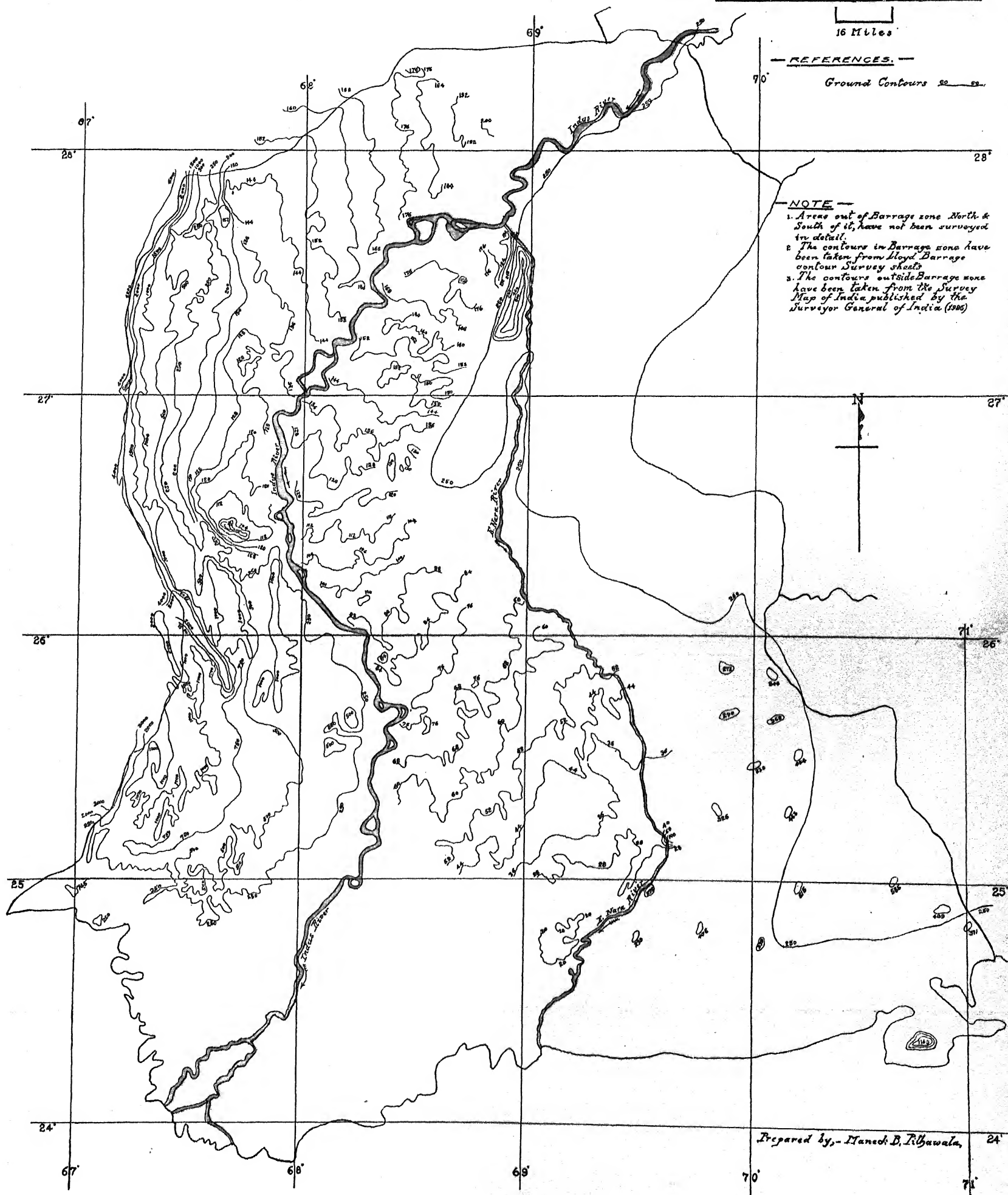
Prepared by,— Maneck B. Pithawala.

— HYDRO–ISOBATHS for OCTOBER–1933 —



— REFERENCES.—
1 Area not Surveyed
2 Barrage Zone
3 Water Logging
4 Sub-soil Water Level Contours

16 Miles

N

Maneck B. Pithawala.

Proc. Ind. Acad. Sci., B, vol. IV, Pl. XXV.
(PLATE 7)

HYDRO–ISOBATHS for APRIL –1934

16 Miles

— REFERENCES —
1. Area not surveyed
2. Barrage Zone
3. Water Logging
4. Sub-soil water level Contours 24 — 24

N

MAP OF SIND
SHOWING SAND & CLAY BELTS

[18 MILES]

REFERENCES
1. Area not Surveyed
2. Investigation Boundary
3. Main Sand Belts
4. Main Clay Belts



Prepared from the data collected at the Development & Research Division
with the kind permission of the Chief Engineer in Sind.

-MAP OF SIND-
-SHOWING KALAR AREAS-

16 MILES

- REFERENCES -
1. Area not Surveyed
2. Investigation Boundary
3. Kalar Areas
4. Water Logged Areas
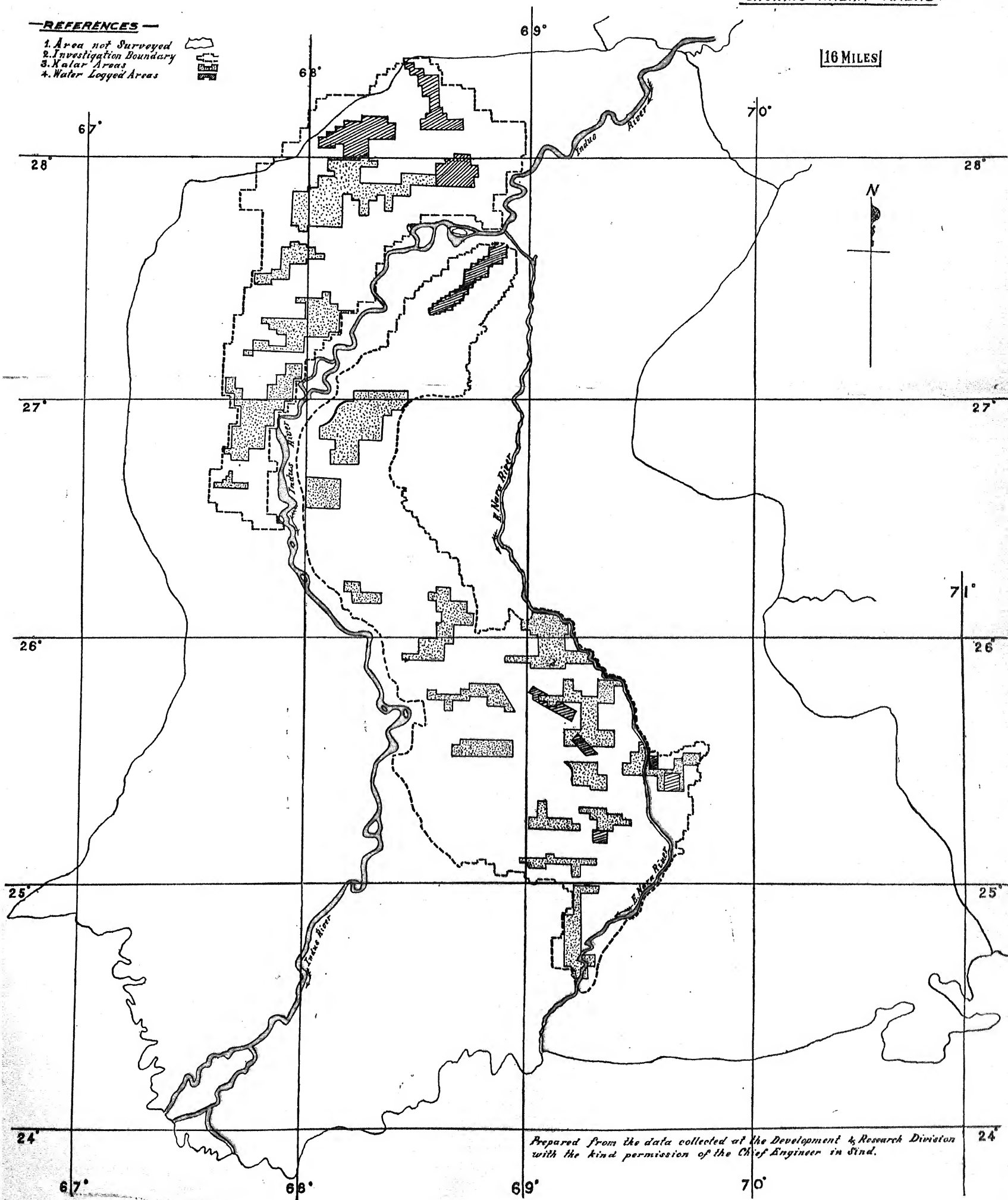
Proc. Ind. Acad. Sci., B, vol. IV, Pl. XXVIII.

(PLATE 10)

Maneck B. Pithawala.

GAUGE AT SUKKUR

RL OF ZERO = 184 + +

DISCHARGE   AT   SUKKUR

Gauge Reading in feet

JANUARY | FEBRUARY | MARCH | APRIL | MAY | JUNE | JULY | AUGUST | SEPTEMBER | OCTOBER | NOVEMBER | DECEMBER
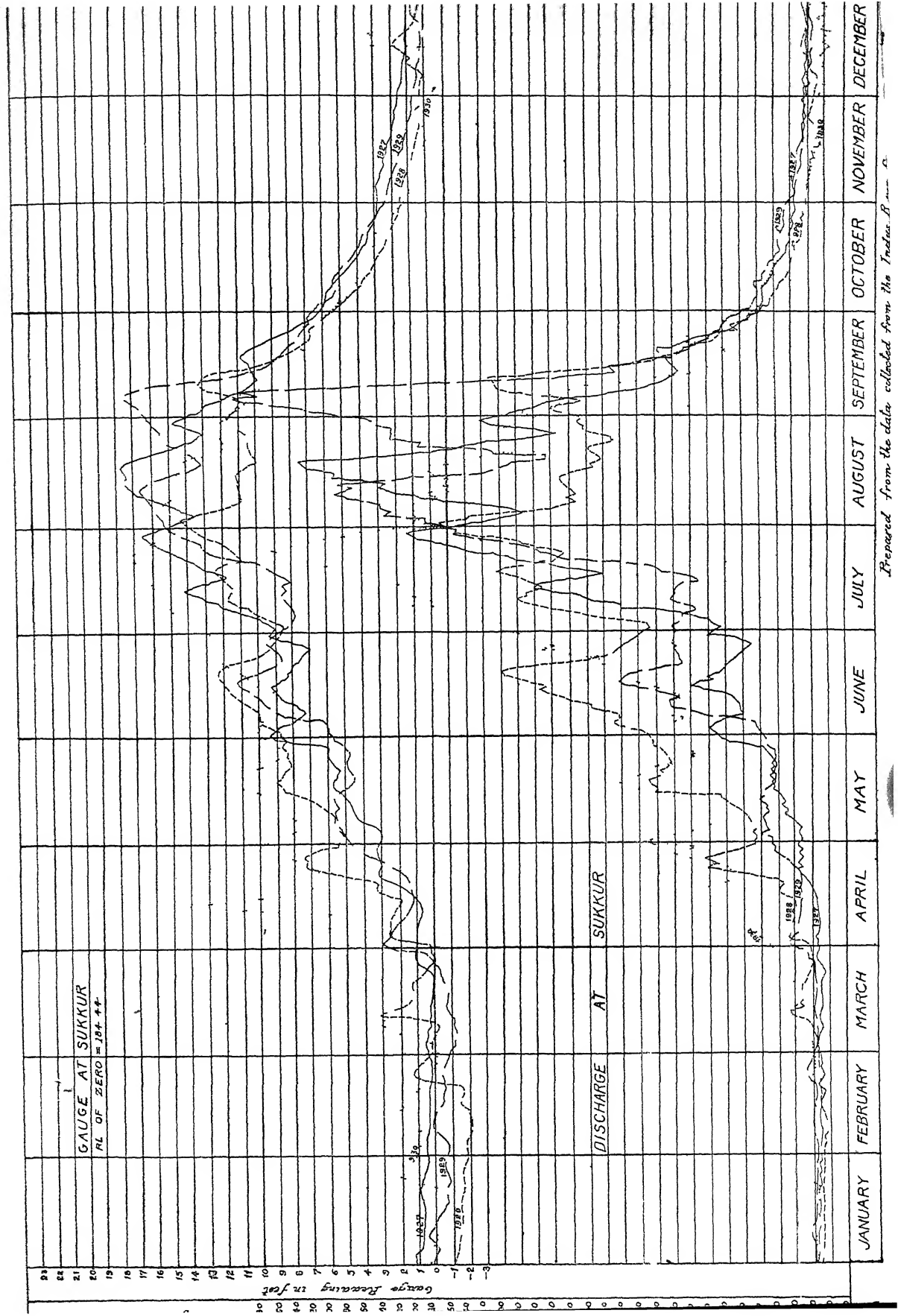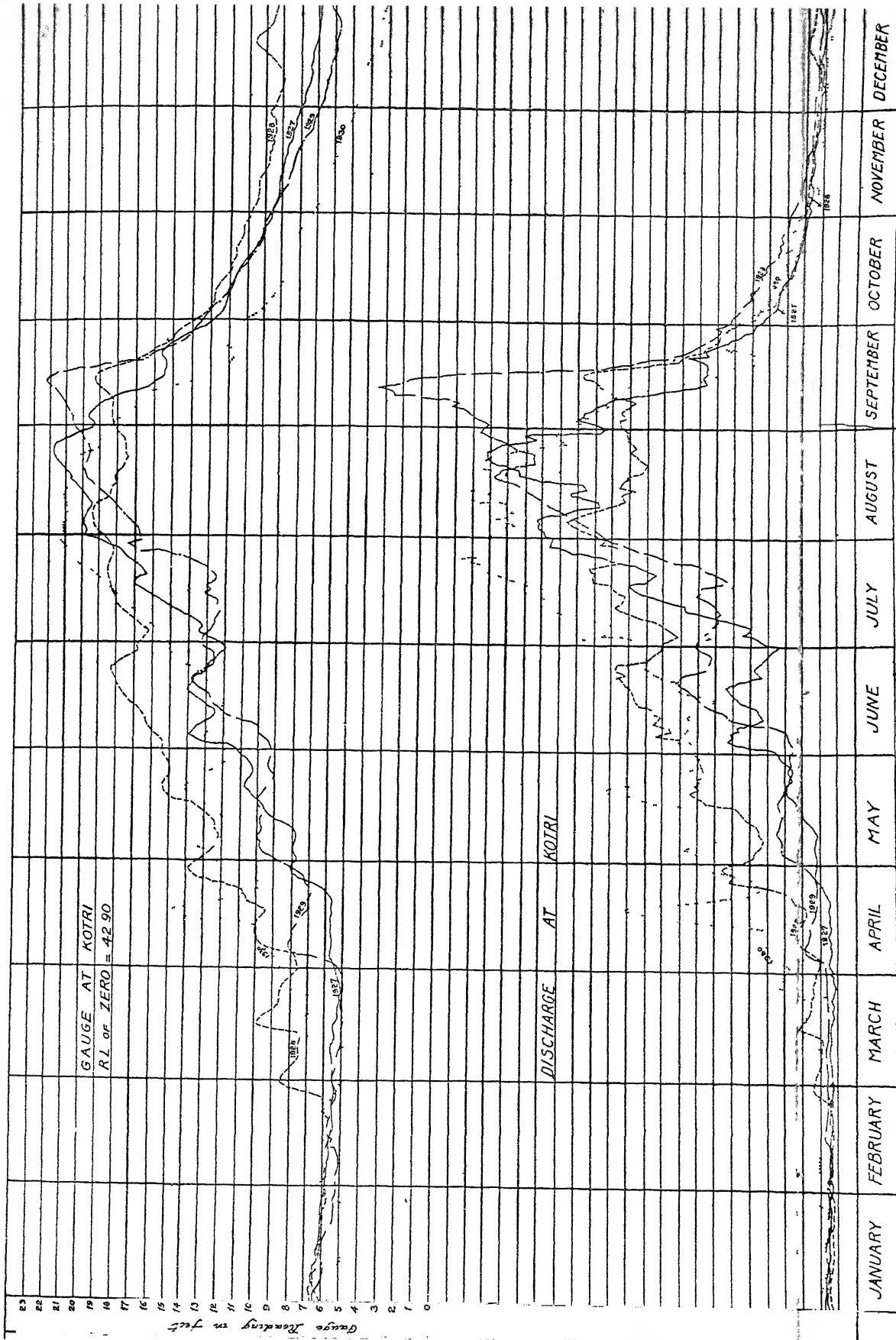
Prepared from the data collected from the Indus River Co.

PLATE 11)

Maneck B. Pithawalla.

GAUGE AT KOTRI

R L OF ZERO = 42.90

DISCHARGE    AT    KOTRI

Gauge Reading in feet

JANUARY | FEBRUARY | MARCH | APRIL | MAY | JUNE | JULY | AUGUST | SEPTEMBER | OCTOBER | NOVEMBER | DECEMBER

Prepared from the data calculated from the Indus River Commission Records

Maneck B. Pithawalla.

**1**

West — 2450' — Peak — Gaj River — Kirthar 4000' — 2000' — Jog Fall — Chelie Hl. — Gaj — Hanchar — East — Indus plain

cretaceous — Kirthar — g

— GENERAL SECTION OF THE KHIRTAR RANGE ON THE NORTHERN BANK OF THE GAJ RIVER —

Approximate Scale Vertical & Horizontal = 1 MILE

a - Alluvium of Indus plain.  b - Munchhar Conglomerates  c - Munchhar Sand stones & Clays
g - Cretaceous  h - Khirtar
d - Gaj  e - Upper Nari  f - Lower Nari
(After Blanford)

**2**

W. — Jakhmari — Strait — E.

— SKETCH SECTION AT JAKHMARI PEAK —

a - Munchhar  b - Khirtar limestone  c - Ranikot beds
d - Trap.  e - Olive shval  x - (Cardita beaumonti bed)
f - Dark sandstone  (After Blanford)

**4**

W. — E.

— SECTION ACROSS SULPHUR - SPRING RAVINE AT LAKHI —

a - Munchar Beds  b - Khirtar Rocks  (After Blanford)

**3**

SW. — Pokran — Dopit — Ranikot — NE.

POKRAN TO RANIKOT
— SECTION ACROSS LAKHI RANGE —

a - Nari  b - Khirtar  (After Blanford)

**5**

W. — S. — 'GOPIR

— SECTION ACROSS SULPHUR-SPRING RAVINE AT Mt 'GOPIR —

a - Nari  b - Gaj  c - Position ; Spring
a - Munchhar beds.

**6**

M̊ Kailas 20026 — Cogra R. — Cogra R. — Jamuna R. — Tribikaz — Kadu — Allah

Ganis — THE INDO BRAHM

— THE INDO-BRAHM —

**7**

— PRESENT KARACHI HARBOUR —

Western Wharf — Eastern Wharf — Keamari Import yard — Chinu Creek — Area to be reclaimed — KEAMARI — MANORA

→ N

**8**

— PLAN OF KEAMARI (ANCIENT) —

Krokola
Kroletry ⎫ Lat 24°50' N
Carangrel ⎭ Long 66°8 E
(After Mascall -1774)

Manora Isl.

Prepared by —Maneck B Pithawalla

Maneck B. Pithawala.

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(PLATE 13)

(1) Sukkur Gauge
(2) Kotri Gauge

SUKKUR MEAN

— MAXIMUM YEARLY READINGS —

KOTRI MEAN

A-B. Fan characterised by a gradient above the average gradient deposition at its head & erosion at its foot (shallow sheet or split-up channels)

B-A. Reach characterised by a gradient below the average erosion at its head & deposition at its foot. (single deep channel)

— MR. R A MOLLOY'S TYPE RIVER & NOTATION —

— Section of Type Alluvial River —

— DIAGRAM TO ILLUSTRATE 2ND & 3RD PRINCIPLES —
— OF DAUSSE. —
(R.D. Oldham)

Fan or Rapid    Reach or Pool    Fan or Rapid
— PLAN —
Steep Gradient    Flat Gradient    Steep Gradient
— SECTION —

160 Miles

— PLAN OF TYPE OR GENERALISATION OF ALLUVIAL RIVER —

High Left Bank or limits of flood wanderings

Main thread of stream

High Right Bank or limits of flood wanderings

Side Channel....
Island........

— THE INDUS RIVER SYSTEM —
SHOWING INDUS LOWER BASIN
— INDEX —

| | |
|---|---|
| I. R. Jhelum | 1 Zaksar |
| II. „ Chenab | 2 Shyok |
| III. „ Ravi | 3 Gilgit |
| IV. „ Beas | 4 Swat |
| V. „ Sutlej | 5 Kunar |
| | 6 Kabul |
| | 7 Kurram |
| | 8 Tochi |
| | 9 Gomal |
| | 10 Kundur |
| | 11 Zob |
| | 12 Soan |
| | 13 Aral |
| | 14 Baran |

Prepared by :— Maneck B. Pithawalla

Maneck B. Pithawala

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(PLATE 14)



MAP SHOWING HYDROGRAPHICAL & OTHER CHANGES IN THE INDUS DELTA
(After M R Haig)

16 Miles

REFERENCES

1. Dotted thick line = Ancient Coast line
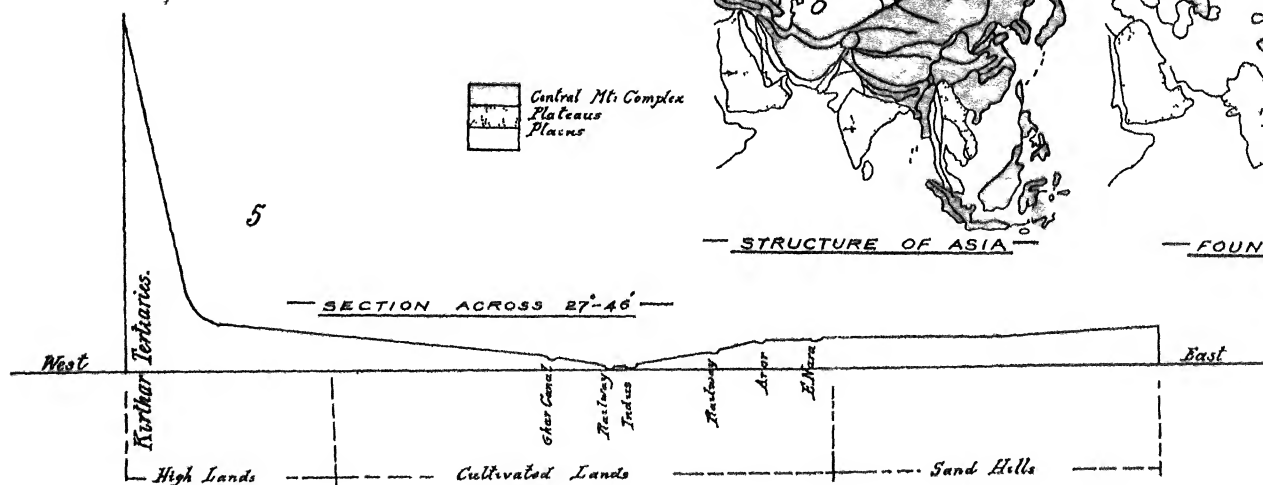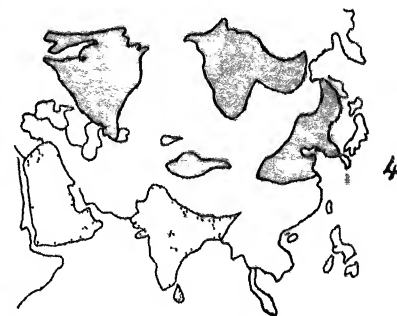2. Thin line = Extent of Delta in Alexanders time
3. Thick line = Extent of Delta in 1887
4. Faint line = Extent of Delta - 1926

NOTE

1. The permanent Channel is limited to A-B about 3 miles long
2. The Sukkur Barrage is constructed just below this neck to ensure its safety

THE INDUS

SHOWING OSCILLATIONS ABOVE & BELOW THE BUKKUR GORGE

STRUCTURE OF ASIA

FOUNDATIONS OF ASIA

Central Mts Complex
Plateaus
Plains

Old Massifs
Remnants of Gondwana land
Reclaimed Land

SECTION ACROSS 27°-46'

West                                                         East

High Lands        Cultivated Lands        Sand Hills

Scale,- Horizontal ---- 16 Miles
        Vertical ---- 1000 feet

SECTION ACROSS 26°-30'

West                                                         East

High Land   Cultivated Land    Irrigated Land    Sand Hills

*Maneck B. Pithawala.*      *Proc. Ind. Acad. Sci., B, vol. IV, Pl. XXXIII.*

(PLATE 15)
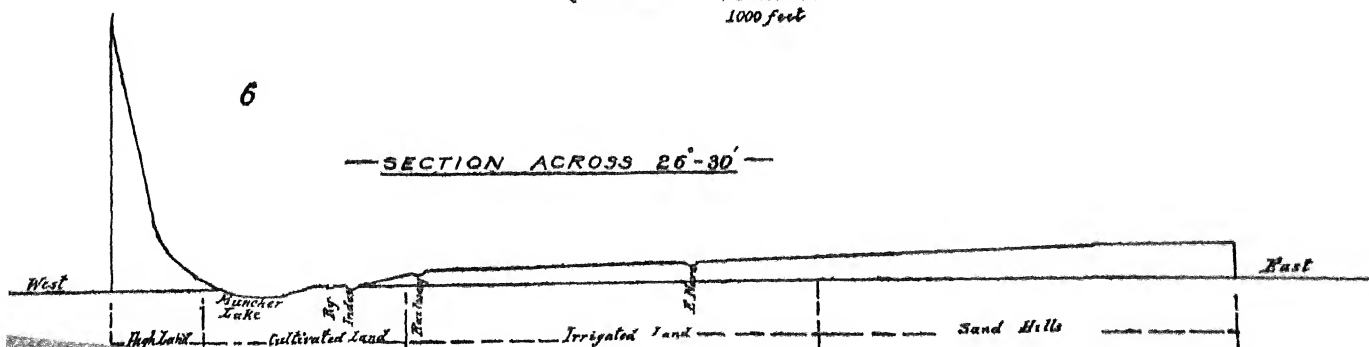
SUBMARINE INDUS GORGE AND GONDWANA CONTINENT.

RELIEF MAP OF SIND.

# GENETICS OF THE *BANSI* WHEAT OF THE BOMBAY-DECCAN AND A SYNTHETIC KHAPLI—PART I.

By B. S. Kadam, M.Sc (Cornell),

*Crop Botanist to the Government of Bombay.*

## *Introduction.*

The *Bansi* wheat (*T. durum*, Desf.) is very extensively cultivated as a dry crop in the Bombay Presidency. The genetic improvement of *Bansi* has been in progress since 1918, resulting in better quality strains which are now spreading in all the major wheat zones of the Presidency.

Most of the high yielding strains of *Bansi* wheat have been crossed with a synthetic Khapli with a view to introduce resistance to black stem rust of wheat. Along with the progress of hybridization genetic data of morphological characters were collected. The inheritance of pubescence of glumes, colour of grain, colour of glumes and colour of awns and their interactions is reported in the present paper.

## *Material and Methods.*

The ♀ parents, *Bansi* 162 and 167, used in the present study, are pure line selections from the *Bansi* wheat (*T. durum*, Desf.). Both the strains have glabrous red glumes and red awns. The grains are plump and yellow in colour.

The ♂ parent, Kala-Khapli 568, has pubescent white glumes and black awns. Its grain is red and long. The original plant of this wheat had pubescent white glumes and black awns and was found in a crop of cultivated Khapli (*T. dicoccum*, Schrk.). The plant proved a hybrid and subsequently a type resembling Khapli, but with black awns and pubescent white glumes, was isolated. It was named Kala-Khapli 568.

With a view to obtain resistant *Bansi*-like types, K.K. 568 was crossed with the *Bansi* strains 162 and 167 during the season of 1927–28.* In the succeeding season, four successful crosses were obtained; three from the

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* The crosses were made by Mr. S. G. Bhalerao, B.Ag., the then Crop Botanist to the Government of Bombay. The next season, Mr. R. K. Kulkarni, B.Ag., then Acting Crop Botanist to the Government of Bombay, grew the $F_1$ plants. The study of $F_2$ and subsequent generations was done by the present writer.

cross ♀ 162 × ♂ K.K. 568 and one from ♀ 167 × ♂ K.K. 568. These were numbered $H_9$, $H_{11}$, $H_{12}$ and $H_{14}$ and yielded in $F_2$ 112, 38, 43 and 146 plants respectively. The whole of the $F_2$ population of each cross was grown separately as the primary object was to obtain desirable economic types. For genetical investigations, however, only $H_9$ and $H_{14}$ were considered as these had larger number of $F_2$ plants. In cross $H_9$, out of the 112 $F_2$ plants only 111 were available for study. In $F_3$, some lines had very few mature plants, due to seedling mortality and other causes. Such lines were therefore discarded and out of 257 cultures of the two crosses only 247 were available in $F_3$. Since the lines were eliminated at random the $F_3$ results are not affected.

The glume and awn colours and glume pubescence were first noted in the field and again checked in the laboratory.

The black awn colour sometimes presented difficulties in diagnosis due to susceptibility to environmental influences. Under adverse climatic conditions, the black colour in awns almost disappears. Plants with black awn colour noted against them in the field were found to have either whitish or reddish awns (depending on red or white glume colour) in the laboratory. Careful observations, however, revealed that in almost all such cases black colouration persisted at the base of the awn. Moreover, complete linkage of black colour of awn and glume hairiness facilitated, without doubt, accurate classification of the character. The grain colours were studied in the laboratory and were easy to classify.

While considering each character, the $F_2$ frequencies of each cross have been shown separately, but have been added together for evaluation to avoid duplicate treatment as the genetical behaviour of both the crosses is absolutely identical. For the same reason, the $F_2$ genotype frequencies, obtained from the 247 cultures of both the crosses available in the $F_3$ generation, are given together.

The data have been evaluated according to Fisher (1932).

### Allelogenic Relations.

(1) *Glume pubescence.*—The hairiness of glumes in wheat has been found to be dominant to non-hairy condition, and both mono- and di-genic ratios have been obtained. In India, the Howards (1912) studied this character in detail and found two types of hair on glumes, short and long, each due to two independent genes giving a 15 : 1 ratio of hairy to glabrous glumed plants in $F_2$.

The glumes of Kala-Khapli are covered all over the surface with a fine felt while the Bansi strains, 162 and 167, have entirely smooth glumes. The

felted glumes were dominant in the $F_1$ generation. In $F_2$, the two types segregated distinctly, giving the following distribution :—

TABLE I.

*Segregation of glume pubescence in* $F_2$.

| Cross | Pubescent glumes (PP) | Glabrous glumes (pp) | Total |
|---|---|---|---|
| $H_9$ (162 × K.K. 568)   .. .. | 87 | 24 | 111 |
| $H_{14}$ (167 × K.K. 568)   .. .. | 112 | 34 | 146 |
| Observed   .. .. | 199 | 58 | 257 |
| Calculated 3 : 1   .. .. | 192·75 | 64·25 | 257 |
| Deviation   .. .. | 6·25 | —6·25 | |

$$X^2 = 0\cdot8106 \; ; \; P \text{ between } 0\cdot30 \text{ and } 0\cdot50.$$

The observed data clearly show a single gene difference. The value of P is between 0·30 and 0·50 for $X^2 = 0\cdot8106$, $n = 1$.

Out of the 247 cultures available in $F_3$ 126 segregated for hairiness, 61 bred true to hairiness and the remaining 60 were glabrous. The $F_3$ results are very close to the expected distribution of 61·75 homozygous pubescent : 123·50 heterozygous pubescent : 61·75 glabrous.

The gene for glume pubescence is designated P. The genetic constitution of Kala-Khapli and *Bansi* 162 and 167 will, therefore, be PP and pp respectively.

(2) *Grain colour.*—Colour in the grain of wheat is due to pigment in testa, and is one of the most important characters used in classification. Most of the wheats have either red or reddish or yellow or yellowish colour in grain. Nilsson-Ehle (1911) was probably the first to investigate the inheritance of this character. He found in $F_2$ 3 : 1, 15 : 1 and 63 : 1 ratios of red to yellow grained plants (Matsuura, 1933). In India, the Howards (1912) confirmed the above ratios in various crosses involving *vulgare, durum* and *compactum* wheats.

In the *Bansi* wheat both red and yellow grained types are found. The *Bansi* strains have yellow grains. The grains of the Kala-Khapli are dull red like that of the ordinary white awned Khapli. In $F_1$ the red colour was

dominant to the yellow condition, and in the next generation, the two types separated clearly. The $F_2$ segregation of both the crosses is shown below :—

TABLE II.

*Segregation of grain colour in $F_2$.*

| Cross | Red grains ($R_1R_1$) | Yellow grains ($r_1r_1$) | Total |
|---|---|---|---|
| $H_9$ | 83 | 28 | 111 |
| $H_{14}$ | 111 | 35 | 146 |
| Observed | 194 | 63 | 257 |
| Calculated 3 : 1 | 192·75 | 64·25 | 257 |
| Deviation | 1·25 | −1·25 | |

$X^2 = 0·0324$ ; P between 0·80 and 0·90.

Out of the total of 257 plants, there are 194 with red grains and 63 with yellow grains. From the expected, the observed frequencies deviate by 1·25 plants only on the basis of a monogenic ratio.

In $F_3$, out of the 247 cultures, all the 59 yellow grained $F_2$ plants bred true. In the red grained group, 64 were homozygous and the remaining 124 segregated in 3 red to 1 yellow ratio showing a very close fit to the theoretical expectation of 61·75 pure red, 123·50 heterozygous red and 61·75 yellow. The gene for red colour of grain is designated $R_1$. The Kala-Khapli and the two *Bansi* strains will therefore be $R_1R_1$ and $r_1r_1$ respectively.

(3) *Glume colour.*—The glumes in wheat may be either black, red (brown) or yellow. Various intensities are found in each. Most of the inheritance studies deal with red and yellow glumed wheats, the former being dominant in most of the cases. The white glume colour of *polonicum*, however, is dominant to the gray chaff of *turgidum*, Biffen (1915) ; and to a black *persicum*, Vavilov and Jakushkina [1925 (*cf.*, Matsuura, 1933)]. Digenic inheritance of 15 red glumed : 1 white glumed plants has also been reported in many species crosses. The Howards (1912) found brown colour of chaff monogenically dominant to white in Indian wheats.

In the *Bansi* wheat, both red and white glumed types are found. The *Bansi* strains, 162 and 167, have red glumes, while Kala-Khapli 568 has white glumes. In $F_1$ the red colour was dominant and in the $F_2$ there was

monogenic segregation of red and white glumed plants. The results are summarised in Table III.

TABLE III.

*Segregation of glume colour in* $F_2$.

| Cross | | | Red glumes ($R_{g-a}$ $R_{g-a}$) | White glumes ($r_{g-a}$ $r_{g-a}$) | Total |
|---|---|---|---|---|---|
| $H_9$ | .. | .. | 86 | 25 | 111 |
| $H_{14}$ | .. | .. | 108 | 38 | 146 |
| Observed | .. | .. | 194 | 63 | 257 |
| Calculated 3 : 1 | .. | .. | 192·75 | 64·25 | 257 |
| Deviation | .. | .. | 1·25 | −1·25 | |

$$X^2 = 0 \cdot 0324 \; ; \; \text{P between } 0 \cdot 80 \text{ and } 0 \cdot 90.$$

Here again there is a very close approximation of the observed segregation with the expected frequencies on the basis of a monogenic ratio. Out of the 257 plants 63 have white glumes and 194 brown glumes, as against the expected 64·25 and 192·75 white and red glumed plants respectively.

The 247 lines in $F_3$ consisted of 65 homozygous for red glumes, 119 heterozygous, segregating in the ratio of 3 red : 1 white, and 63 pure for white glumed plants.

The red glume gene causes also red awn colour (see under glume and awn colours). It is, therefore, designated $R_{g-a}$; the subscripts *g* and *a* denote glume and awn respectively.

(4) *Awn colour.*—The same type of inheritance as has been previously reported by the writer (1931) was found in the crosses under consideration. As the interrelations of the above characters are considered in this paper it is considered desirable to present $F_2$ data on the segregation of awn colour in the present material.

Inheritance of awn colour was first reported by the Howards (1912), who found black awn colour monogenically dominant to white. Kadam and Nazareth (1931) found in $F_2$ a ratio of 12 black : 3 red : 1 white awned plants in a cross between a black and a red awned type. The results indicated the presence of two independent genes for black and red awns, the former being epistatic. Recently, Sigfússon (1932) reported black awn colour monogenically dominant to white in a progeny of a cross between Marquis and Iumilla.

In the material under consideration the black awn colour was dominant to red in $F_1$ and in the next generation segregation was in the proportion of 12 black : 3 red : 1 white.   The $F_2$ results are given in the following table :—

TABLE IV.

*Segregation of awn colour in $F_2$.*

| Cross | Awn colours | | | Total |
|---|---|---|---|---|
| | Black $(BR_{g\text{-}a}+Br_{g\text{-}a})$ | Red $(bR_{g\text{-}a})$ | White $(br_{g\text{-}a})$ | |
| $H_9$        .. | 87  | 16  | 8   | 111 |
| $H_{14}$     .. | 112 | 22  | 12. | 146 |
| Observed     .. | 199 | 38  | 20  | 257 |
| Cal. 12 : 3 : 1 .. | 192 | 48  | 16  | 256 |
| Deviation    .. | 7   | —10 | —4  | —1  |

$X^2 = 3 \cdot 3385$ ;  P between $0 \cdot 10$ and $\cdot 20$.

The results are in agreement with the previous findings.   Formerly, the genes for black and red awns colours were designated B and R respectively. Since the gene for red glumes produces red awns also, it is now renamed as $R_{g\text{-}a}$.

From the data presented in the above tables, it is clear that the genes for red grain colour $(R_1)$ and felted glumes $(P)$, in Kala-Khapli 568 are mono-genically dominant to the yellow grain colour $(r_1)$ and smooth chaff $(p)$ of the *Bansi* strains 162 and 167.   The gene B for black awn colour in K.K. 568, is epistatic to $R_{g\text{-}a}$ which causes red colour in both awns and glumes of the *Bansi* strains.   In $F_2$, due to recombination of the recessive genes, b and $r_{g\text{-}a}$, a new type with white glumes and awns appears.   The interrelations of the various genes will be considered now.

*Intergenic Relations.*

(5) *Glume pubescence and grain colour.*—The following distribution of the $F_2$ population was observed when both the characters were considered together.

TABLE V.

*Independent segregation of glume pubescence and grain colour in* $F_2$.

| Cross | Pubescent glumes with grains | | Glabrous glumes with grains | | Total |
|---|---|---|---|---|---|
| | Red ($PR_1$) | Yellow ($Pr_1$) | Red ($pR_1$) | Yellow ($pr_1$) | |
| $H_9$ .. | 65 | 22 | 18 | 6 | 111 |
| $H_{14}$ .. | 90 | 22 | 21 | 13 | 146 |
| Observed .. | 155 | 44 | 39 | 19 | 257 |
| Cal. 9 : 3 : 3 : 1 .. | 144 | 48 | 48 | 16 | 256 |
| Deviation .. | 11 | —4 | —9 | 3 | —1 |

$$X^2 = 3 \cdot 4235 ; \quad P \text{ between } 0 \cdot 30 \text{ and } 0 \cdot 50.$$

For $n = 3$ the $X^2$ value falls between $0 \cdot 30$ and $0 \cdot 50$ showing that the agreement between the theoretical and observed number is good. The genes P and $R_1$ are therefore inherited independently.

(6) *Glume pubescence and colour*.—When the characters, colour of glumes and glume pubescence were considered together the following distribution was obtained in $F_2$.

TABLE VI.

*Independent segregation of glume pubescence and colour of glumes in* $F_2$.

| Cross | Pubescent glumes with colour | | Glabrous glumes with colour | | Total |
|---|---|---|---|---|---|
| | Red ($PR_{g-a}$) | White ($Pr_{g-a}$) | Red ($pR_{g-a}$) | White ($pr_{g-a}$) | |
| $H_9$ .. | 70 | 17 | 16 | 8 | 111 |
| $H_{14}$ .. | 86 | 26 | 22 | 12 | 146 |
| Observed .. | 156 | 43 | 38 | 20 | 257 |
| Cal. 9 : 3 : 3 : 1 .. | 144 | 48 | 48 | 16 | 256 |
| Deviation .. | 12 | —5 | —10 | 4 | —1 |

$$X^2 = 4 \cdot 6041 ; \quad P \text{ between } 0 \cdot 20 \text{ and } 0 \cdot 30.$$

The deviations in the $PR_{g-a}$ and $pR_{g-a}$ groups are rather large. The value of P however is well above the significant level. The agreement between the expected and actual numbers is, therefore, well within the random fluctuation.

The red glume colour gene $R_{g-a}$ is also independent of the gene P for pubescence.

(7) *Glume pubescence and awn colours.*—When the $F_2$ progenies were analysed for awn colours and glume pubescence it was found that the hairiness of the glumes was completely associated with black colour of awns in K.K. 568. The $F_2$ frequencies are given below :—

TABLE VII.

*Associated segregation of glume pubescence and black awn colour in $F_2$.*

| Cross | Felted glumes with awns | | | Glabrous glumes with awns | | | Total |
|---|---|---|---|---|---|---|---|
| | Black ($PBR_{g-a} + PBr_{g-a}$) | Red | White | Black | Red ($pbR_{g-a}$) | White ($pbr_{g-a}$) | |
| $H_9$ | 87 | 0 | 0 | 0 | 16 | 8 | 111 |
| $H_{14}$ | 112 | 0 | 0 | 0 | 22 | 12 | 146 |
| Observed | 199 | 0 | 0 | 0 | 38 | 20 | 257 |
| Cal. 12 : 3 : 1 | 193 | 0 | 0 | 0 | 48 | 16 | 257 |
| Deviation | 6 | 0 | 0 | 0 | —10 | 4 | |

$X^2 = 3 \cdot 2698$ ; P between $0 \cdot 10$ and $0 \cdot 20$.

It will be seen from the table above that no combination of glabrous glumes and black awns appears. In $F_3$ also no case of a break between the two characters was observed. There is thus an unbreakable linkage between the black awn colour gene B and the pubescent glume gene P. The segregation shown in the table would, therefore, approximate a 12 : 3 : 1 ratio. On this basis the agreement between the obtained and actual numbers is satisfactory. The value of P is between $0 \cdot 10$ and $0 \cdot 20$ for $X^2 = 3 \cdot 2698$.

(8) *Grain and glume colours.*—The grain and glume colours showed the following $F_2$ segregation when considered together.

TABLE VIII.

*Independent segregation of grain and glume colours in* $F_2$.

| Cross | Red grains with glumes | | Yellow grains with glumes | | Total |
|---|---|---|---|---|---|
| | Red ($R_1R_{g-a}$) | White($R_1r_{g-a}$) | Red ($r_1R_{g-a}$) | White ($r_1r_{g-a}$) | |
| $H_9$ .. | 61 | 22 | 25 | 3 | 111 |
| $H_{14}$ .. | 82 | 29 | 26 | 9 | 146 |
| Observed .. | 143 | 51 | 51 | 12 | 257 |
| Cal. 9 : 3 : 3 : 1 .. | 144 | 48 | 48 | 16 | 256 |
| Deviation .. | —1 | 3 | 3 | —4 | —1 |

$$X^2 = 1 \cdot 3819 ; \quad P \text{ between } 0 \cdot 70 \text{ and } 0 \cdot 80.$$

The observed numbers show an excellent fit to the calculated frequencies. The $X^2$ value is quite small, showing that the deviations from the expectation are not at all significant. The genes $R_{11}$ and $R_{g-a}$ are independent.

(9) *Grain and awn colours.*—When the distribution of grain colour along with the three awn colours was considered the following frequencies were observed in the $F_2$ generation.

TABLE IX.

*Independent segregation of grain and awn colours in* $F_2$.

| Cross | Red grains with awns | | | Yellow grains with awns | | | Total |
|---|---|---|---|---|---|---|---|
| | Black ($R_1BR_{g-a}$) | Red ($R_1bR_{g-a}$) | White ($R_1br_{g-a}$) | Black ($r_1BR_{g-a}$) | Red ($r_1bR_{g-a}$) | White ($r_1br_{g-a}$) | |
| $H_9$ .. | 65 | 11 | 7 | 22 | 5 | 1 | 111 |
| $H_{14}$ .. | 90 | 13 | 8 | 22 | 9 | 4 | 146 |
| Observed .. | 155 | 24 | 15 | 44 | 14 | 5 | 257 |
| Cal. 36 : 9 : 3 : 12 : 3 : 1 .. | 144 | 36 | 12 | 48 | 12 | 4 | 256 |
| Deviation .. | 11 | —12 | 3 | —4 | 2 | 1 | —1 |

$$X^2 = 6 \cdot 5068 ; \quad P \text{ between } 0 \cdot 20 \text{ and } 0 \cdot 30.$$

On a trigenic basis the observed numbers closely correspond to the calculated frequencies except in the red grained-red awned group which shows a large deficiency.  As a consequence the $X^2$ value for the class increases unduly.  The value of P however is between 0·20 and 0·30 for $n = 5$.  The deviations may, therefore, be ascribed to chance.  The data clearly demonstrate the independent relations of the genes for grain and awn colours.

(10)  *Glume and awn colours.*—It has been shown above (Table III) that the difference between the red and white colour of glumes is monogenic and the awn colours, black and red, are controlled by two independent genes (Table IV).  Therefore three genes may involve in the production of glume and awn colours.  But when the distribution of glume and awn colours is considered together, a new situation arises.  Instead of a tri-genic, a di-genic grouping is obtained in $F_2$ as will be seen from the following table :—

TABLE X.

*Segregation of glume and awn colours in $F_2$.*

| Cross | Red glumes with awns | | | White glumes with awns | | | Total |
|---|---|---|---|---|---|---|---|
| | Black ($Rg$-$a$B) | Red ($Rg$-$a$b) | White | Black ($rg$-$a$B) | Red ($rg$-$a$b) | White ($rg$-$a$b) | |
| H$_9$ | 70 | 16 | 0 | 17 | 0 | 8 | 111 |
| H$_{14}$ | 86 | 22 | 0 | 26 | 0 | 12 | 146 |
| Observed | 156 | 38 | 0 | 43 | 0 | 20 | 257 |
| Cal. 9 : 3 : 3 : 1 | 144 | 48 | 0 | 48 | 0 | 16 | 256 |
| Deviation | 12 | −10 | 0 | −5 | 0 | 4 | −1 |

$X^2 = 4·6041$ ; P between 0·20 and 0·30.

It will be noticed that out of the six possible combinations only four appear in the $F_2$ generation.  The red glumed-white awned and the white glumed-red awned combinations do not occur at all.  If it is assumed that one and the same gene is responsible for the production of red colour in both glumes and awns then we expect four phenotypes.  Indeed, on this assumption the agreement between the actual and theoretical frequencies is satisfactory.

The $F_3$ behaviour fully supported the above contention.  There were four types of red glumed-black awned plants in $F_2$.  Those that :—(1) bred true, (2) segregated in 3 red glumed-black awned : 1 red glumed-red awned, (3) segregated in 3 red glumed-black awned : 1 white glumed-black awned

and (4) gave ratios of 9 red glumed-black awned : 3 red glumed-red awned : 3 white glumed-black awned : 1 white glumed-white awned.

Among the red glumed-red awned group there were only two types ; (1) pure and (2) segregating in 3 red glumed-red awned : 1 white glumed-white awned plant.

The white glumed-black awned $F_2$ plants also showed two types of behaviour ; (1) pure and (2) segregating in 3 white glumed-black awned : 1 white glumed-white awned.

The fourth group consisted of white glumed-white awned plants. All of these bred pure in the $F_3$ generation, indicating that these were double recessive in constitution.

Further proof was adduced by grouping the $F_2$ population according to the genotypes. In the table below observed and expected frequencies of the various genotypes are given.

TABLE XI.

*Distribution of glume and awn colour genotypes in* $F_2$.

| Genotype | | Observed | Expected | Deviation |
|---|---|---|---|---|
| 1 $R_{g \cdot a}$ $R_{g \cdot a}$ BB | .. | 18 | 15·44 | 2·56 |
| 2 $R_{g \cdot a}$ $R_{g \cdot a}$ Bb | .. | 35 | 30·88 | 4·12 |
| 2 $R_{g \cdot a}$ $r_{g \cdot a}$ BB | .. | 33 | 30·88 | 2·12 |
| 4 $R_{g \cdot a}$ $r_{g \cdot a}$ Bb | .. | 60 | 61·75 | −1·75 |
| 1 $R_{g \cdot a}$ $R_{g \cdot a}$ bb | .. | 13 | 15·44 | −2·44 |
| 2 $R_{g \cdot a}$ $r_{g \cdot a}$ bb | .. | 29 | 30·88 | −1·88 |
| 1 $r_{g \cdot a}$ $r_{g \cdot a}$ BB | .. | 11 | 15·44 | −4·44 |
| 2 $r_{g \cdot a}$ $r_{g \cdot a}$ Bb | .. | 29 | 30·88 | −1·88 |
| 1 $r_{g \cdot a}$ $r_{g \cdot a}$ bb | .. | 19 | 15·44 | 3·56 |
| Total .. | | 247 | 247·03 | −0·03 |

$X^2 = 3·8812$ ; P between 0·80 and 0·90.

It is obvious from the above table that the $F_2$ genotype distribution is in confirmation with the theoretical. For $n = 8$, the $X^2 = 3·8812$ gives a

value of P. lying between 0·80 and 0·90. That is, the departures from the expectation are fortuitous and have no significance.

: The genes B and $R_{g-a}$ are independent. The former is epistatic to the latter in the awn region, allowing $R_{g-a}$ to express in the glumes only.

## Discussion.

. The study of interrelations of genes in the *Bansi* wheats 162 and 167 and Kala-Khapli 568 has brought to light two interesting features. The gene $R_{g-a}$ causes red colour in both glumes and awns, and is hypostatic to the black awn colour gene B in the awn region. Thus, in the presence of B and $R_{g-a}$ the plants have red glumes and black awns.

The fact that only a single gene $R_{g-a}$ is able to cause colour in both glumes and awns explains the occurrence of only two types of plants, red glumed-red awned, and white glumed-white awned in the *Bansi* wheat (*T. durum*, Desf.). Percival (1921) and Vavilov *et al.* (1931) found red and white awns always associated with red and white glumes respectively, while black awns appear on all the three types of glumes. Evidently, in *Triticum* there are separate genes for black colour of awns and glumes, but red or white colours in glumes and awns are caused by one and the same gene. It is most probable that in some wheats black colour in both glumes and awns may be caused by one and the same gene.

The black colour of the awn and the pubescence of glumes are completely linked in Kala-Khapli 568. The writer is not aware of any previous case of linkage between these two characters. However, cases of linkage between glume colours and glume pubescence are on record. Biffen (1905, 1915), Kezer and Boyack (1918) and Percival (1921) found complete linkage of black colour of glumes and pubescence in crosses between *turgidum* × *vulgare*, *vulgare* × *dicoccum* and *dicoccum* × *sphærococcum*, respectively. Engledow (1914), as mentioned by Hayes and Garber (1927), obtained partial repulsion phase linkage (1 : 3 : 3 : 1) in a cross of a synthetic glabrous black glumed wheat and a pubescent white glumed Essex Rough Chaff.

The complete linkage of black colour of awn with glume pubescence throws light on the probable origin of Kala-Khapli 568. As mentioned under " Material and Methods " the strain was obtained from a natural hybrid, with black awns and pubescent glumes, found in a crop of ordinary Khapli which has glabrous white glumes and awns. . Naturally the other parent of the original plant must have possessed black awns and pubescent glumes. In the Bombay Presidency only one variety, Baxi (*T. durum*, var. *melanopus*, Korn.), with black awns and pubescent glumes is grown as an irrigated crop like the Khapli. It is thus highly probable that a natural cross must have

occurred in a field of Baxi and Khapli growing side by side. This assumption is supported by the fact that in crosses between Kala-Khapli 568 and Baxi the writer (unpublished results) did not obtain any segregation for either awn colours or for pubescence of glumes. The genes for black awn colour and pubescence of glumes are therefore the same in Baxi and Kala-Khapli 568. It therefore appears certain that Baxi and Khapli are the parents of Kala-Khapli.

## Summary.

1. Data are presented on the genic relations of glume pubescence, grain colour, glume colour and awn colours in crosses between two pure line selections of *Bansi* wheat (*T. durum*, Desf.) and a synthetic black awned pubescent glumed Khapli.

2. The hairiness of glumes is due to a gene P in Kala-Khapli 568 and is dominant to the glabrous (p) condition in the *Bansi* wheat. The gene P is completely linked with the black awn colour gene, B.

3. The red colour of grain in Khapli 568 is dominant to the yellow grain of *Bansi*. The gene $R_1$ is independent of genes for other characters.

4. The red glume colour of the *Bansi* wheat is caused by a gene $R_{g-a}$ which also produces red awn colour, but behaves hypostatic to the black awn colour gene, B, in the awn region. The recessive alleles of B and $R_{g-a}$ result in white-glumed white-awned plants.

5. The probable origin of Kala-Khapli 568 is indicated.

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# UREASE ACTIVITY OF GERMINATED SEEDS.

By A. Venkatasubban, (Miss) R. Karnad
AND
N. N. Dastur.

*(From the Department of Biochemistry, Indian Institute of Science, Bangalore.)*

THE observation that the urease activity of soya bean extracts increases on germination of the seed was reported in 1931, by Wei Sun Tao and Shigeru Komatsu. Similar results were reported by Yutaka Jono (1931) with germinated water-melon and pumpkin seeds. An inquiry into the cause of such an increase forms the subject of the present paper.

The increase in the activity of the extracts of germinated seeds may be due to (1) production of activators or destruction of inhibitors during the process of germination, (2) increase in the absolute quantity of the enzyme, and/or (3) greater ease in extractability of the enzyme from the germinated seed material as compared with the resting seed material. Ornithine and a few other amino acids are among the activators (Naosaburo Kato, 1923 ; Husa, 1926), and germination is accompanied by the breakdown of proteins leading to an increase in the soluble amino acids. Tao and Komatsu (*loc. cit.*) have studied the changes in the protein nitrogen attendant on germination and observed that the protein is converted into soluble nitrogenous compounds during the process and that in the aqueous extracts of germinated seeds, nitrogen in amide and mono-amino forms predominates. While the probability of an increase in activity on germination due to liberation of activators is thus indicated, no work bearing on the influence of the other factors has so far been reported. A preliminary note bearing on this subject has recently been published (Sastri and Sundara Iyengar, 1935).

## Experimental.

The investigation reported in this paper was carried out with two varieties of soya bean (*Glycine hispida*, Sieb and Zucc), the Burmese and $K_{16}$ (obtained from the Government Agricultural Farm, Mysore), two varieties of jack beans (*Canavalia ensiformis*, DC.), the red and white, horse gram (*Dolichos biflorus*, Linn.) and red gram (*Cajanus indicus*, Spreng.) obtained locally. The seeds were soaked in running water for 36 hours and spread out for germination. Two days later, when the radicles and plumules had

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noticeably developed, the seeds were dried in the sun, powdered to pass through 60-mesh sieve and stocked in stoppered bottles. The ungerminated seeds were also sun-dried and powdered as above.

*Preparation of Extracts.*—Preliminary experiments showed that reproducible results were obtained with defatted powders. The seed material was shaken up with petrol ether for 30 minutes and the residue after filtration, air dried and bottled. 10 g. of the meal was shaken up with 50 c.c. of distilled water for one hour and centrifuged, and the centrifugate employed for the estimation of the urease activity. For the estimation of the activity, 5 c.c. of the extract, corresponding to 1·0 g. of the powder was incubated with 10 c.c. of 1·0 per cent. urea solution in borax-borate buffer (pH = 6·9) for 30 minutes at 30°·0 C. and the amount of ammonia nitrogen at the end of this period was estimated by the titrimetric method developed by Dastur, *et al.* (1935). The ammonia nitrogen (in mg.) released was taken as a measure of the urease activity.

It was previously ascertained that shaking for one hour at the room temperature (22°·0–25°·0 C.) extracted most of the enzyme. Thus, in one experiment, 10·0 g. of the seed meal was shaken up with 50 c.c. of water for one hour and centrifuged. About 40 c.c. of the extract were thus obtained. The residue was again shaken up with 40 c.c. of water for one hour and centrifuged. The extractions were thus repeated with further additions of 40 c.c. of water in each case. Table I gives the activities of three successive extracts thus obtained.

TABLE I.

*Urease activity of aqueous extracts.*

| Extract No. | I | II | III |
|---|---|---|---|
| Activity in mg. of ammonia nitrogen   ..       ..        .. | 10·4 | 2·2 | 0·5 |

It is clear from the above results that the first extraction removes the major part of the enzyme that is extractable. The activities shown by the second and third extracts are largely due to the active extract remaining in the residue after centrifuging.

Similar results were obtained with 20 per cent. alcohol and 50 per cent. glycerine. In the· following experiments, aqueous extracts obtained as above were employed for urease activity determination.

Table II gives the total and amino nitrogen in the extracts obtained from a few seed materials. The analyses of the dry powders from the materials are given in Table III.

TABLE II.

*Analysis of extracts.\**

| Seed Material | Total Solids | | Total N | | Amino N | | pH | |
|---|---|---|---|---|---|---|---|---|
| | Ger. | Unger. | Ger. | Unger. | Ger. | Unger. | Ger. | Unger. |
| *Glycine hispida* (Burmese) | 2·38 | 2·12 | 0·148 | 0·096 | 0·057 | 0·017 | 6·2 | 6·2 |
| *Glycine hispida* ($K_{16}$) .. | 4·09 | 2·85 | 0·391 | 0·232 | 0·161 | 0·016 | 6·0 | 6·0 |
| *Dolichos biflorus* .. .. | 2·84 | 2·70 | 0·258 | 0·246 | 0·043 | 0·022 | 6·0 | 6·0 |
| *Canavalia ensiformis* .. | 2·58 | 2·89 | 0·246 | 0·121 | 0·022 | 0·021 | 6·0 | 6·0 |

\* From 10 gms. of dry powder.

TABLE III.

*Analysis of dry powders.*

| Seed Material | PERCENTAGES | | | |
|---|---|---|---|---|
| | Total N | | Ash | |
| | Ger. | Unger. | Ger. | Unger. |
| *Glycine hispida* (Burmese) .. | 6·40 | 5·75 | 5·77 | 5·76 |
| *Glycine hispida* ($K_{16}$) .. | 6·17 | .. .. | 5·31 | 5·28 |
| *Dolichos biflorus* .. | 3·78 | 3·61 | 2·92 | 3·10 |
| *Canavalia ensiformis* .. | 4·01 | 3·84 | 3·35 | 3·20 |

The most significant change is in the amino-nitrogen content of the extracts, confirming the results obtained by Tao and Komatsu (*loc. cit.*).

Table IV gives the urease activities of germinated and resting seed materials.

TABLE IV.

*Urease activity\* of germinated and ungerminated seeds.*

| Seed Material | Urease activity (in mg.) of ammonia nitrogen | |
|---|---|---|
| | Germinated | Ungerminated |
| *Glycine hispida* (Burmese)       | 17·40 | 16·25 |
| *Glycine hispida* (K₁₆)          | 12·85 | 12·45 |
| *Dolichos biflorus* I          | 8·69 | 4·76 |
| *Dolichos biflorus* II          | 7·15 | 5·65 |
| *Canavalia ensiformis* (white) I       | 27·30 | 19·06 |
| *Canavalia ensiformis* (white) II       | 38·15 | 35·15 |
| *Canavalia ensiformis* (red)       | 12·93 | 11·55 |
| *Cajanus indicus*          | 9·20 | 5·66 |

\* Values refer to 1.0 g. of dry powder.

The results clearly show that with the various seed materials tried, the urease activity of the extracts of the germinated seeds is invariably higher than that of the resting seeds, thus confirming the observations of the previous workers.

The above experiments were repeated using the germinated and ungerminated seed powders instead of aqueous extracts. The powders (1·0 g. in the case of the ungerminated seeds and an equivalent weight after correction for respiration and other losses in the case of the germinated seeds) were weighed out into flasks, toluene added, and with the help of a glass rod with a flattened end, the powders were well dispersed. 10 c.c. of 1·0 per cent. urea solution in buffer of pH 6·9 was then added and, after incubation for 30 minutes, ammonia nitrogen was estimated by the acetone titration method (*loc. cit.*). The urease activities are expressed in mg. of ammonia nitrogen produced (Table V).

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TABLE V.

*Urease activity of powders.*

| Seed Material | Urease activity in mg. of ammonia nitrogen | |
| --- | --- | --- |
| | Germinated | Ungerminated |
| *Glycine hispida* (Burmese) .. .. | 20·40 | 22·10 |
| *Glycine hispida* ($K_{16}$) .. .. .. | 12·85 · | · 14·00 |
| *Dolichos biflorus* I .. .. .. | .. 9·95 | 10·50 |
| *Dolichos biflorus* II .. .. .. | 7·60 | 7·75 |
| *Canavalia ensiformis* (white) .. .. | 37·10 | 42·90 |
| *Cajanus indicus* .. .. .. | 9·10 | 9·75 |

The results show that in all the cases the activity of the germinated seed powder is higher than that of the ungerminated seed powders.

*Discussion.*

A comparison of Tables IV and V shows that while with extracts the activity is higher with germinated seeds than with the resting seeds, the reverse is observed when the corresponding powders are employed. The activity of the powders should be considered as the true measure of the urease content because even if the enzyme exists in the absorbed condition in the seed material it is capable of exerting its hydrolysing action when brought into contact with the substrate. It may be mentioned in this connection that in the system urea-urease-charcoal, although the enzyme is quantitatively adsorbed on the surface of the charcoal, yet the reaction velocity is the same as in the system devoid of charcoal (Przylecki, *et al.*, 1927). Similar observations have been made with other enzymes. It is thus clear that there is actually no significant increase in the amount of enzyme produced as a result of germination. The results also exclude the possibility of the activity being influenced by any activators. The only possibility that remains is that as a result of germination the extractability of the enzyme from the seed material is facilitated.

The germinated seed powders, due to respiration during the period of germination, show a smaller activity after correcting for the loss in weight than the resting seeds (*cf.* Table IV): in fact preliminary experiments with mixtures of extracts indicate that the addition of germinated seed extracts

to extracts derived from the ungerminated seeds tends to decrease the activity of the letter.

From the figures presented in Tables IV and V, it will be seen that, on an average about 90 per cent. of the total quantity of the enzyme is extracted in the case of germinated seeds ; whereas under similar conditions of extraction only less than 70 per cent. of the urease is extracted from the resting seed powders. It is also clear that the increase in activity on germination is only apparent and is due to greater facility of extraction brought about as a result of the breakdown of the complex materials to which the enzyme is in some way bound. In other words, germination effects the conversion of a ' *desmo* ' enzyme into a ' *lyo* ' enzyme. The germination should therefore be viewed as a process, leading to the solubilisation of the *desmo* enzyme. Further work is necessary to characterise the two forms of enzymes present in the resting seeds.

*Summary.*

The urease activity of the extracts of germinated seeds (*Glycine hispida, Dolichos biflorus, Canavalia ensiformis, Cajanus indicus*) is higher than that of extracts derived from resting seeds. On the other hand, the urease activities of the germinated seed powders are somewhat lower than those from the resting seeds. The difference between the activities of extracts and powders is readily explained on the assumption that germination brings about the solubilisation of the *desmo* enzyme present in the resting seeds.

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# GROWTH AND WATER REQUIREMENT OF CROP PLANTS IN RELATION TO SOIL MOISTURE.

By B. N. SINGH, D.SC.,

AND

B. R. SINGH, M.SC.

*(From the Institute of Agricultural Research, Benares Hindu University, Benares.)*

## *Introduction.*

A REQUISITE supply of water for the proper growth and development of plants is one of the vital problems confronting the agriculturist in both the arid and flooded localities. In such areas it is essential from a purely economic point of view that the supply of irrigation to the soil must scientifically be regulated to meet the demand made by the growing plants at their critical periods of water requirement such that the maximum possibilities of growth and yield might be ensured. The necessity of proper irrigation is felt all the more when we take into consideration that an excessive supply of the same occasionally leads to poor soil aeration while a deficiency below a certain minimum usually results in wilting, both of which seriously affect the growing individual.

While a critical study of the problem of water requirement from several points of view has found prominence in a previous contribution[11] from this Experiment Station, in the investigations to be presently discussed an attempt is made to study the relation between soil moisture and the growth and water requirement of plants both under excessive and deficient supply of the same. In all such studies dealing with soil water the question of proper aeration is of vital importance. Clements[6] as far back as 1907 realised the importance of soil aeration in initiating successful plant growth. Balls[1] noted local asphyxiation of cotton plants in water-logged soils, with the result that death and decomposition of plant tissue soon became evident. Harrison and Aiyer[8] observed more or less similar phenomenon in paddy. Fowler and Lipman[7] working on deficient supply of water in the soil observed that an increase of water content upto a certain critical concentration added to the growth of lemons, no augmentation being observed with further addition of water beyond this limit. The control of transpiration by the saturation deficit in soils has also been stressed in an earlier paper.[11] How far an increase in water-supply to the fields will bring about an increase

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in the ultimate growth and yield of the plant ; in what manner, and at what stage of the life-cycle, a deficiency in the same would enable the plant to withstand drought and allow it to remain above its wilting level ; what would be the optimum water content of soil to induce maximum growth and yield; and whether soil and plant characteristics can in any way influence the availability of water from the field ?—are the questions to the elucidation of which the present enquiry is in the main directed.

### Methods and Materials.

Pot culture was taken recourse to in the production of an average uniform crop. The upper layer of the farm soil, having a superstructure of a typical loam, was well mixed with ⅓ farmyard manure and sieved to remove the bigger particles of *kankar*. The pots were filled with this uniform mixture of soil and manure, and were watered and well worked out before sowing. The mixture was analysed with respect to several mechanical constituents and the moisture equivalent, wilting coefficient, and hygroscopic coefficient maintained at 13·1, 7·1 and 4·9 respectively. The moisture content of soil is however varied between 25–100% of water-holding capacity regulating the quantity of water-supply. Twelve grades of soil moisture, namely, 100, 90, 80, 70, 65, 60, 55, 50, 45, 37, 31, and 25% of water-holding capacity were thus maintained and the soil moisture in per cent of dry soil and available water are also given (Table 1A), the limit of saturation in each case being determined by incubating the soil at 100°C to constant weight and calculating the moisture content per 100 grams fresh weight.

### TABLE (1A).

| Soil moisture in % of water-holding capacity of soil | Soil moisture in % of dry soil | Available water |
|:---:|:---:|:---:|
| 100 | 41·87 | 34·67 |
| 90 | 37·68 | 30·48 |
| 80 | 33·49 | 26·29 |
| 70 | 29·31 | 22·11 |
| 65 | 27·22 | 20·02 |
| 60 | 25·12 | 17·92 |
| 55 | 23·03 | 15·83 |
| 50 | 20·94 | 13·73 |
| 43 | 18·01 | 10·80 |
| 37 | 15·49 | 8·29 |
| 31 | 12·98 | 5·78 |
| 25 | 10·47 | 3·27 |

Pure strains of *Triticum vulgare* (var. Pusa 4), *Hordeum vulgare* (var. Pusa 21), *Brassica botrytis* (var. snow ball), *Brassica campestris* (var. Golden ball), *Beta vulgaris* (var. long smooth blood red), *Brassica caulorapa* (var. early mammoth), *Raphanus sativus* (var. Country raddish) were raised in pots under optimal conditions of nutrition, water-supply and aeration unless otherwise required, at the Experimental Farms. When the plants were well established they were sorted and grouped in twelve sets each maintained at a certain percentage of water-supply as indicated above. Only average healthy plants were used for experimental purposes and the amount of transpiration determined by the loss-in-weight method. For details of the procedure and experimental technique reference may be made to a previous communication[11] from this Experiment Station.

The thoroughly sealed containers with the plant exposed to atmosphere were weighed every morning and evening at intervals of every twelve hours, and the loss of water as judged by the decrease in the weight of the container was calculated to per 1000 sq. cm. of transpiring surface. The soil moisture content was maintained at the original level by the requisite addition of fresh water to the extent lost by it. Fresh set of plants were used after a week's interval, at the end of which the plants already experimented upon were taken out of the pots, carefully washed and incubated to constant weight in a steam oven regulated at 100° C. For each series of such determinations usually six potted plants were used and the rate of transpiration as well as the dry weight determined separately in each case. At successive stages of growth the water requirement was calculated on the basis of water transpired per unit dry weight of the plant inclusive of roots (*cf.* 11). Only the average of the six determinations is given in the tables and the data are statistically tested as to their significance by calculating the probable error of the means.

The evaporating power of the atmosphere was measured by the loss of water from a shallow water surface as discussed previously[10] and calculated to per 1000 sq. cm. of the evaporating surface. Care was taken to see that water was always maintained to the extent of 3″ in depth and the loss made good every evening by the requisite addition of the same.

For determining the wilting coefficient of the different ' type ' soils, representative samples of the same were dug out, pulvarised, sieved through a two-millimetre sieve and finally mixed with the requisite quantity of water to bring their moisture content to 22 per cent of the dry weight. Extreme care was taken to ensure uniformity in texture to avoid variations in the quantity of non-available moisture consequential to stratification or non-uniformity of the soil mass and the soil particles thoroughly mixed with water to ensure uniform supply of the same throughout.

As representatives of the different soil types commonly found in nature, typical sand, loam and clay were used for experimental purposes besides green manured loam, loam containing 20 per cent of sodium nitrate, lime, superphosphate and nisiphos respectively. In every case uniformity of texture and water content was maintained throughout the whole mass.

The uniform soil so prepared was loosely packed in separate glass tumblers and not more than two plants were allowed to grow in it. Wax-seal method was used to check the loss of water from the soil by means other than transpiration from the plants. A wax petrolatum mixture containing 80 per cent of bees-wax and 20 per cent petrolatum was found to adhere well to the sides of the glass as well as the soils on cooling, when it formed a perfect seal through which the plants emerged air-tight. ·

The experimental pots with the plants growing therein were immersed in a constant temperature bath to the extent of ·5 cm. from the rim in order to avoid the effect of sudden fluctuations in atmospheric temperature. This was mainly done to avoid the condensation on the inner walls of the pot as a result of distillation from the soil due to temperature differences. This condensed water may be absorbed by the roots in contact with the inner walls of the pot with the consequent reduction in the available soil moisture of the principal soil mass much below the minimum limit.

When the potted plants indicated the stage of permanent wilting, that is, when addition of fresh water did not result in their recovery, the soil moisture content was determined on dry weight basis and the percentage of non-available moisture calculated. The moisture-holding capacity, moisture equivalent and hygroscopic coefficient were also estimated after the methods followed by Briggs and Shantz.[4]

As representatives of crop plants, weeds, and vegetables, pure strains of *Zea Mays* (*var.* yellow round), *Andropogan sorghum* (*var.* local), *Triticum vulgare* (*var.* Pusa 4), *Cyanodon dactylon* (*var.* hariali), *Crotalaria juncea* (*var.* local), *Hibiscus esculantus* (*var.* white velvet), *Brassica olarasia* (*var.* caulorapa) and *Brassica botrytis* (*var.* snow ball) were selected for experimentation. Only young plants were used for experimentation on wilting coefficient, mature ones being not used on account of the complications in sealing the pots as well as the difficulty in the use of big pots with the inadequacy of maintaining similar moisture content and temperature throughout the different regions of soil mass.

## Experimental Findings.

*Effect of various grades of soil moisture content on the rate of transpiration.*—In Series I, the plants were grown under various grades of soil moisture and

the rate of transpiration determined at successive stages throughout the life-cycle of the plants. A perusal of Figs. 1, 2 and 3 and Tables I, II and III representing the relation between transpiration and moisture content of the soil at three distinct stages of the life-cycle shows that evaporation of water from leaves is greatly influenced by the moisture content of the soil. In the seedling
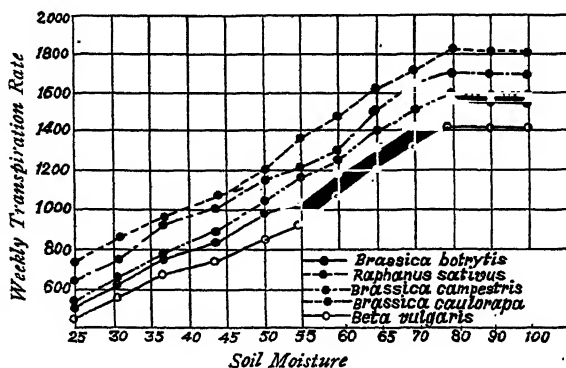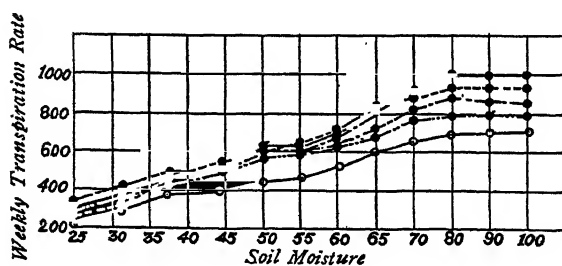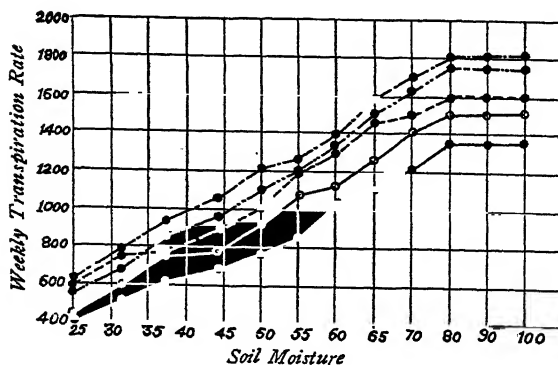


FIGS. 1-3.  Weekly transpiration rate of crop plants in seedling (Fig. 1), adolescent (Fig. 2) and maturity (Fig. 3) stages under varying percentages of soil moisture.

TABLE I.

*Weekly transpiration rate\* of plants during the seedling stage under varying soil moisture content.*

| Soil moisture in % of water-holding capacity | Triticum vulgare | Hordeum vulgare | Brassica botrytis | Brassica caulorapa | Beta vulgaris | Brassica campestris | Raphanus sativus |
|---|---|---|---|---|---|---|---|
| % | gm. | gm. | gm. | gm. | gm. | gm. | gm. |
| 25 | 3?2 | 375 | 496 | 520 | 417 | 612 | 712 |
| 31 | 509 | 496 | 602 | 636 | 532 | 725 | 842 |
| 37 | 625 | 602 | 743 | 756 | 665 | 892 | 956 |
| 45 | 703 | 692 | 826 | 870 | 712 | 1,002 | 1,065 |
| 50 | 815 | 798 | 958 | 1,031 | 834 | 1,144 | 1,204 |
| 55 | 896 | 871 | 1,037 | 1,165 | 912 | 1,208 | 1,365 |
| 60 | 1,004 | 984 | 1,181 | 1,240 | 1,055 | 1,304 | 1,480 |
| 65 | 1,098 | 1,068 | 1,315 | 1,395 | 1,204 | 1,498 | 1,615 |
| 70 | 1,206 | 1,172 | 1,439 | 1,520 | 1,326 | 1,642 | 1,721 |
| 80 | 1,276 | 1,225 | 1,554 | 1,615 | 1,435 | 1,745 | 1,845 |
| 90 | 1,271 | 1,219 | 1,552 | 1,612 | 1,432 | 1,742 | 1,822 |
| 100 | 1,278 | 1,224 | 1,556 | 1,612 | 1,428 | 1,747 | 1,814 |

\* Calculated to per 1,000 sq. cm. area of leaf surface.

stage (Fig. 1) to take an example, the increase in the percentage of water beyond 25 per cent of water-holding capacity results in a characteristic rise in the transpiration rate of leaves, the greater the moisture content of the soil, the greater is the loss of water from the plants. This is characteristically noted not only in the case of one plant but, to be sure, in all the representative types studied. In every case transpiration increases till 80 per cent of water-holding capacity of soil. This optimal value of soil moisture having been reached, further increase in moisture content seems to have no direct relation with the transpiration curve which at first shows a rounding off and later attains a level phase so characteristic of optima and limiting factor curves.

Another notable feature of the curves at practically all the three stages of the life-cycle is that plants belonging to different genera and species, although exhibiting the same proportional increase till 80 per cent of water-holding capacity, show remarkable gradation in the specific transpiring power. All the plants experimented upon in this series are grown under similar environmental conditions and transpiration studies also conducted at practically the same period of the day. In spite of this similarity in the environmental conditions of the plants experimented upon individual variations are but apparent between the different types, indicating thereby that under uniform conditions of environment also the transpiration is greatly regulated by
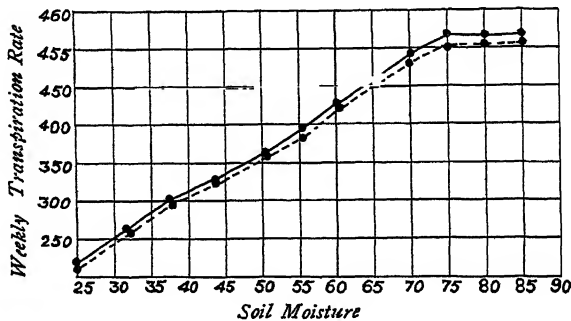


FIG. 4.
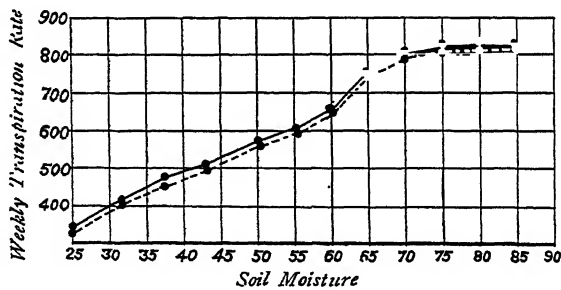


FIG. 5.
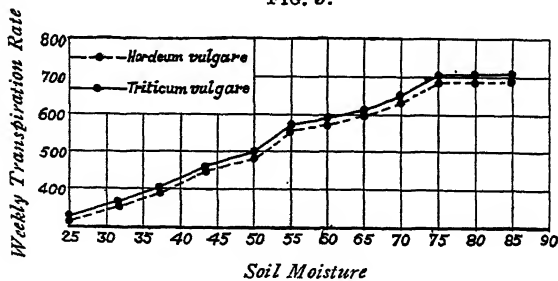


FIG. 6.

FIGS. 4, 5 & 6. Weekly transpiration rate of *T. vulgare* and *H. vulgare* under varying percentages of soil moisture at seedling stage (Fig. 4), 28 days old (Fig. 5) and 56 days old (Fig. 6) respectively.

TABLE II.

*Weekly transpiration rate\* in different crops during the adolescent stage
28 days after germination under varying soil moisture content.*

| Soil moisture in % of water-holding capacity | Triticum vulgare | Hordeum vulgare | Brassica botrytis | Brassica caulorapa | Beta vulgaris | Brassica campestris | Raphanus sativus |
|---|---|---|---|---|---|---|---|
| % | gm. | gm. | gm. | gm. | gm. | gm. | gm. |
| 25 | 376 | 361 | 322 | 290 | 242 | 345 | 272 |
| 31 | 485 | 468 | 407 | 355 | 302 | 426 | 324 |
| 37 | 576 | 538 | 442 | 391 | 384 | 492 | 435 |
| 43 | 625 | 610 | 511 | 489 | 391 | 502 | 541 |
| 50 | 712 | 705 | 609 | 582 | 445 | 593 | 602 |
| 55 | 767 | 748 | 635 | 596 | 475 | 602 | 645 |
| 60 | 839 | 828 | 708 | 645 | 522 | 648 | 724 |
| 65 | 995 | 982 | 827 | 689 | 596 | 732 | 845 |
| 70 | 1,076 | 1,055 | 922 | 765 | 665 | 829 | 884 |
| 80 | 1,105 | 1,086 | 1,007 | 789 | 701 | 876 | 946 |
| 90 | 1,118 | 1,085 | 1,005 | 789 | 695 | 856 | 924 |
| 100 | 1,122 | 1,086 | 1,007 | 792 | 697 | 849 | 921 |

\* Calculated to per 1,000 sq. cm. area of leaf surface.

the specificity of the plant material. Figs. 4, 5 and 6 representing transpiration of *Triticum* and *Hordeum* plants at three distinct stages of the life-cycle under varying percentages of soil moisture indicate more or less similar nature of response. Beyond 80 per cent water-holding capacity in the case of cereals also no increase in transpiration takes place when moisture content of the soil is increased although the proportionality is continuously kept up till this percentage.

Plants belonging to the same family or closely allied ones seem to be possessed of practically the same transpiring power under varying conditions of soil moisture. Specially is this characteristic towards the close of the

life-cycle when the transpiration curves of the plants belonging to the same or allied family overlap one another. This is remarkable in the case of *Triticum* and *Hordeum* as well as *Brassica botrytis* and *Brassica caulorapa*, stressing thus that the plants belonging to closely connected families have similar transpirational response to varying conditions of soil moisture.

TABLE III.

*Weekly transpiration rate\* in different crops at the maturity stage 56 days after germination under varying soil moisture content.*

| Soil moisture in % of water-holding capacity | Triticum vulgare | Hordeum vulgare | Brassica botrytis | Brassica caulorapa | Beta vulgaris | Brassica campestris | Raphanus sativus |
|---|---|---|---|---|---|---|---|
| % | gm. | gm. | gm. | gm. | gm. | gm. | gm. |
| 25 | 238 | 228 | 402 | 560 | 462 | 645 | 602 |
| 31 | 288 | 278 | 526 | 583 | 592 | 772 | 732 |
| 37 | 349 | 336 | 608 | 865 | 745 | 956 | 768 |
| 43 | 428 | 421 | 677 | 972 | 791 | 1,075 | 885 |
| 50 | 486 | 472 | 798 | 1,106 | 925 | 1,221 | 1,009 |
| 55 | 598 | 578 | 856 | 1,209 | 992 | 1,286 | 1,092 |
| 60 | 625 | 602 | 1,041 | 1,318 | 1,128 | 1,389 | 1,302 |
| 65 | 658 | 642 | 1,129 | 1,472 | 1,284 | 1,578 | 1,403 |
| 70 | 715 | 704 | 1,219 | 1,608 | 1,426 | 1,715 | 1,507 |
| 80 | 792 | 778 | 1,358 | 1,698 | 1,521 | 1,825 | 1,598 |
| 90 | 796 | 772 | 1,362 | 1,692 | 1,525 | 1,818 | 1,602 |
| 100 | 796 | 780 | 1,356 | 1,699 | 1,521 | 1,815 | 1,589 |

\* Calculated to per 1,000 sq. cm. area of leaf surface.

The observations thus recorded indicate that a decrease in the percentage of soil moisture below 80 per cent water-holding capacity usually results in decreasing transpiration. It may be thus possible to reduce transpirational loss of water by decreasing the soil moisture, but how far an attempt in this

direction will be helpful from the economic point of ultimate growth and yield is the question. To throw light on this aspect of the problem the relation between the water content of the soil and the ultimate out-turn of dry matter in plants is studied.

*Relation between soil-water-content and ultimate growth.*—In Series II the plants above referred to, are grown under identically similar conditions as in the previous series. The soil moisture is varied between 25 and 100 per cent of water-holding capacity of soil as before in the different sets, and the plants in each set are allowed to grow under same saturation limit throughout their life-cycle. At the end of each week a number of plants from each set are taken and incubated to constant weight at 100° C. and the dry weight recorded.
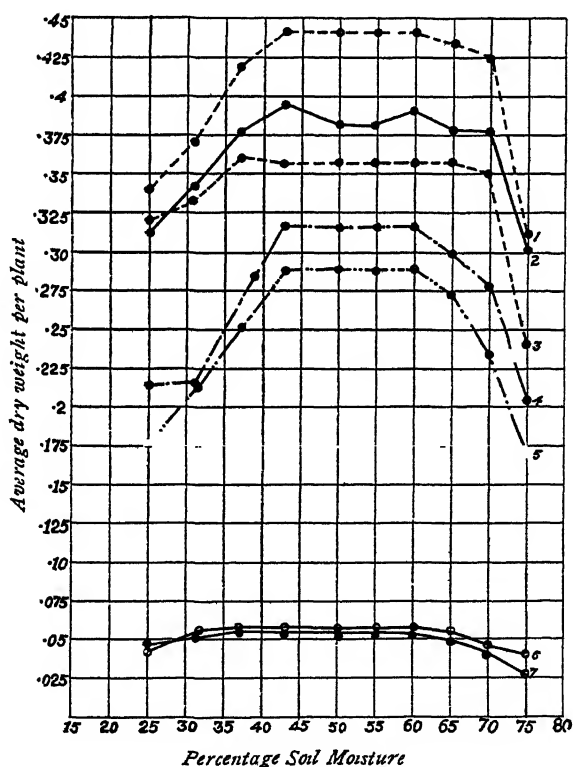


FIG. 7. Average dry weight per plant under varying percentages of soil moisture at seedling stage.

1. *Brassica botrytis.*    2. *Raphnus sativus.*    3. *Brassica caulorapa.*    4. *Beta vulgaris.*
5. *Brassica campestris.*    6. *Triticum vulgare.*    7. *Hordeum vulgare.*
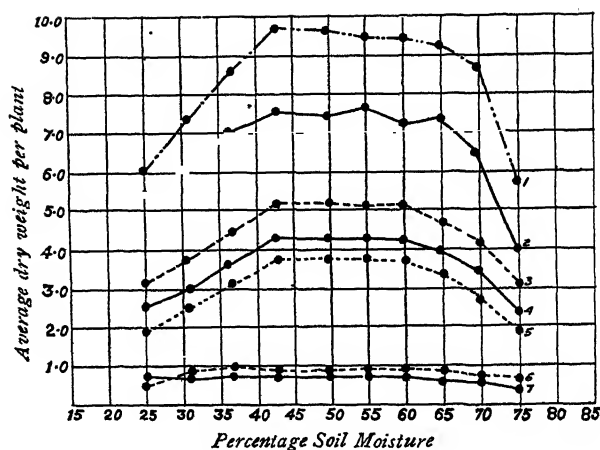
FIG. 8.    Average dry matter per plant in adolescent stage under varying percentages of soil moisture.

1. *Brassica botrytis.*    2. *Brassica caulorapa.*    3. *Raphnus sativus.*    4. *Beta vulgaris.*
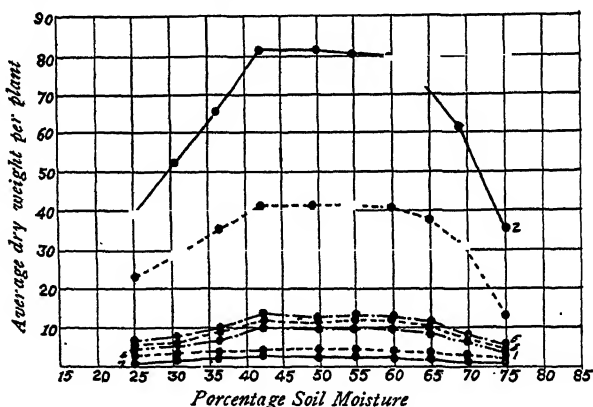5. *Brassica campestris.*    6. *Triticum vulgare.*    7. *Hordeum vulgare.*



FIG. 9.    Average dry matter per plant at maturity stage in varying percentages of soil moisture.

1. *Brassica botrytis.*    2. *Brassica caulorapa.*    3. *Raphnus sativus.*    4. *Beta vulgaris.*
5. *Brassica campestris.*    6. *Triticum vulgare.*    7. *Hordeum vulgare.*

Figs. 7, 8 and 9 and Tables IV–VI represent the growth of the experimental plants under the varying conditions of soil moisture. To take an example, a reference to Fig. 7 dealing with the growth in the seedling stage remarkably indicates that the production of dry matter is considerably influenced by the variations in the moisture content of the soil. In case of *Hordeum* and *Triticum* the differences seem to be insignificant, whereas in other cases variations in the extent and magnitude of growth under varying conditions of soil moisture are but apparent. The curves in general exhibit an ascending phase till 37 per cent of water-holding capacity of soil moisture.

TABLE IV.

*Average dry weight of plants during the seedling stage at the close of first week under varying moisture content of the soil.*

| Soil moisture in % of water-holding capacity | *Triticum vulgare* | *Hordeum vulgare* | *Brassica campestris* | *Brassica botrytis* | *Brassica caulorapa* | *Beta vulgaris* | *Raphanus sativus* |
|---|---|---|---|---|---|---|---|
| % | gm. | gm. | gm. | gm. | gm. | gm. | gm. |
| 25 | 0·045 | 0·043 | 0·172 | 0·337 | 0·316 | 0·210 | 0·311 |
| 31 | 0·052 | 0·055 | 0·207 | 0·370 | 0·329 | 0·210 | 0·342 |
| 37 | 0·055 | 0·057 | 0·248 | 0·418 | 0·357 | 0·283 | 0·375 |
| 43 | 0·055 | 0·057 | 0·286 | 0·439 | 0·355 | 0·314 | 0·392 |
| 50 | 0·055 | 0·057 | 0·286 | 0·440 | 0·356 | 0·313 | 0·380 |
| 55 | 0·056 | 0·057 | 0·286 | 0·440 | 0·355 | 0·312 | 0·380 |
| 60 | 0·057 | 0·055 | 0·287 | 0·440 | 0·356 | 0·314 | 0·390 |
| 65 | 0·056 | 0·052 | 0·270 | 0·436 | 0·358 | 0·300 | 0·378 |
| 70 | 0·047 | 0·043 | 0·236 | 0·425 | 0·349 | 0·281 | 0·375 |
| 80 | 0·041 | 0·029 | 0·166 | 0·333 | 0·236 | 0·204 | 0·300 |

Further increase does not augment the production of dry matter in any way, the curves more or less maintaining a horizontal course. This level phase is remarkable till 60 per cent of water-holding capacity of soil moisture, any increase beyond this resulting in a decrease in the out-turn of the dry matter.

The inflexion of the ascending phase to a horizontal one in case of cereals seems to be brought about in the vicinity of 37 per cent of water-holding capacity, whereas in the case of vegetables, in general, a slightly higher percentage is required, optimal growth is observed only when soil moisture is beyond 45 per cent of water-holding capacity. This brings to light the fact that vegetables in general require greater saturation in soil for their optimal growth.

The growth of plants towards the later stages of their life-cycles as represented in Figs. 8 and 9 exhibit more or less similar fluctuations. Although variations in the amount of dry matter in different cases are apparent, the

TABLE V.

*Average dry weight per plant for different grades of soil moisture.*
*at the end of 5th week during the adolescent stage.*

| Soil moisture in % of water-holding capacity | Triticum vulgare | Hordeum vulgare | Brassica campestris | Brassica botrytis | Brassica caulorapa | Beta vulgaris | Raphanus sativus |
|---|---|---|---|---|---|---|---|
| % | gm. | gm. | gm. | gm. | gm. | gm. | gm. |
| 25 | 0·56 | 0·49 | 2·05 | 6·61 | 5·95 | 2·65 | 3·42 |
| 31 | 0·69 | 0·70 | 2·67 | 8·03 | 6·68 | 3·13 | 4·10 |
| 37 | 0·84 | 0·76 | 3·34 | 9·50 | 7·70 | 3·98 | 4·85 |
| 43 | 0·84 | 0·76 | 4·06 | 10·70 | 8·30 | 4·64 | 5·61 |
| 50 | 0·83 | 0·76 | 4·05 | 10·60 | 8·20 | 4·65 | 5·60 |
| 55 | 0·87 | 0·76 | 4·06 | 10·50 | 8·40 | 4·65 | 5·60 |
| 60 | 0·81 | 0·69 | 4·07 | 10·50 | 8·10 | 4·64 | 5·63 |
| 65 | 0·73 | 0·62 | 3·71 | 10·20 | 8·04 | 4·28 | 5·14 |
| 70 | 0·55 | 0·49 | 3·01 | 9·58 | 7·22 | 3·73 | 4·60 |
| 80 | 0·46 | 0·31 | 2·00 | 6·43 | 4·23 | 2·55 | 3·40 |

saturation limit for initiating optimal growth remains practically the same in different cases. The response to increase of water-supply seems to be felt more in the case of vegetables towards the close of the life-cycle, *Brassica caulorapa* and *Brassica botrytis* exhibiting the maximal response. Small variations in moisture content till 45 per cent of water-holding capacity induces many-fold increase in dry matter.

Another remarkable point that is to be noted is that the curves in different cases, below and above a certain percentage of soil moisture, converge towards each other. This further indicates that growth is affected somehow by either a decrease in the moisture content below a certain mini-mum percentage or an increase in the same beyond the critical maxima.

It is thus clear that optimal growth in cereals may be secured at 37 per cent of water-holding capacity or more, and in the case of vegetables at 45 per cent of water-holding capacity and higher. Below these critical points the growth seems to be limited by the percentage of soil moisture and as such

## TABLE VI.

*Average dry matter per plant in different grades of soil moisture during the presenescent stage 63 days after germination.*

| Soil moisture in % of water-holding capacity | Triticum vulgare | Hordeum vulgare | Brassica botrytis | Brassica caulorapa | Beta vulgaris | Brassica campestris | Raphanus sativus |
|---|---|---|---|---|---|---|---|
| % | gm. | gm. | gm. | gm. | gm. | gm. | gm. |
| 25 | 4·5 | 3·0 | 9·0 | 78·2 | 46·1 | 12·0 | 11·0 |
| 31 | 6·0 | 5·0 | 12·6 | 106·1 | 58·0 | 15·2 | 14·1 |
| 37 | 8·0 | 6·0 | 16·3 | 134·3 | 72·7 | 20·6 | 18·0 |
| 43 | 8·0 | 6·0 | 21·0 | 165·0 | 85·0 | 26·0 | 23·0 |
| 50 | 7·8 | 6·1 | 21·5 | 166·3 | 85·0 | 26·2 | 22·7 |
| 55 | 8·4 | 6·0 | 20·8 | 165·0 | 85·6 | 25·7 | 23·1 |
| 60 | 6·9 | 5·0 | 21·3 | 164·7 | 84·7 | 26·5 | 23·3 |
| 65 | 5·4 | 4·1 | 18·1 | 151·0 | 78·5 | 22·8 | 20·0 |
| 70 | 3·8 | 2·9 | 13·8 | 127·1 | 64·4 | 18·7 | 16·4 |
| 80 | 2·6 | 1·7 | 8·5 | 76·0 | 31·0 | 11·8 | 10·8 |

in all studies on growth care must be taken in maintaining the soil moisture above the critical minimum. We might advantageously turn our attention to studying the water requirements of crops in relation to soil moisture, to throw further light on the question of the relative efficiency of soil moisture in regulating growth and transpiration in plants.

*Relation between soil moisture and water requirement of crops.*—In Series III the experimental plants were grown as before under varying percentages of soil moisture throughout their life-cycle and their water requirement under several grades of soil moisture determined by the method adopted previously.[11]
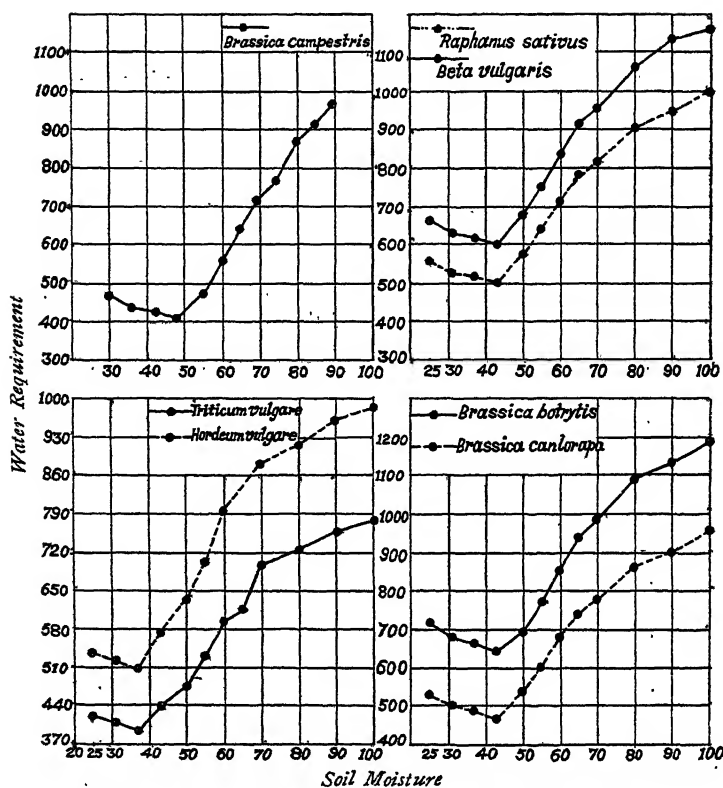
FIG. 10.  Water requirement of different crop plants under varying grades of soil moisture.

A survey of Fig. 10 and Table VII representing the water requirement under different percentages of soil moisture in the experimental plants indicates that the curves are generally divisible into two main regions. In the first place, the decline phase is to be noted reaching a minimum value at a certain concentration to be followed later on by a continuous rising phase. In case of cereals this minimal point is to be located in the vicinity of 37 per cent of water-holding capacity whereas for the vegetables the minimum is found to lie at 45 per cent of water-holding capacity of soil.

The fall in water requirement curve with increase in the moisture content till 37 per cent water-holding capacity in case of cereals and 45 per cent of water-holding capacity in vegetables indicates that for unit dry matter production, the amount of water required becomes less and less as the soil moisture is increased towards the optimum point. From purely practical point of view the experimental results lead us to conclude that cereals and vegetables grown under 22 and 28 per cent of water-holding capacity would exhibit the maximum possibilities of growth.

## TABLE VII.

*Water requirement of crop plants under different grades of soil moisture.*

| Soil moisture in % of water-holding capacity | Water requirement of crops | | | | | | |
|---|---|---|---|---|---|---|---|
| | *Triticum vulgare* | *Hordeum vulgare* | *Brassica botrytis* | *Brassica caulorapa* | *Beta vulgaris* | *Brassica campestris* | *Raphanus sativus* |
| 25 | 424±4·2 | 538±1·6 | 535±3·4 | 720±4·5 | 575±3·2 | 622±2·6 | 682±4·5 |
| 31 | 414±5·3 | 525±4·1 | 505±4·3 | 684±2·3 | 546±1·6 | 596±2·1 | 648±7·2 |
| 37 | 398±1·6 | 510±6·2 | 494±1·6 | 668±3·6 | 534±3·1 | 588±4·2 | 635±5·3 |
| 43 | 442±3·1 | 576±5·3 | 475±3·2 | 645±1·6 | 520±3·5 | 572±5·3 | 615±5·7 |
| 50 | 480±2·7 | 636±4·6 | 542±3·5 | 698±2·7 | 591±4·3 | 628±7·8 | 690±3·8 |
| 55 | 536±3·7 | 705±3·9 | 605±5·1 | 772±5·2 | 654±2·6 | 696±3·8 | 762±6·1 |
| 60 | 595±1·7 | 765±2·5 | 681±6·1 | 856±5·3 | 728±5·6 | 778±3·2 | 848±7·4 |
| 65 | 620±3·2 | 796±2·7 | 742±2·3 | 940±6·8 | 794±4·2 | 581±1·3 | 924±4·3 |
| 70 | 698±4·1 | 878±4·2 | 780±2·7 | 984±4·5 | 826±3·4 | 892±2·6 | 968±4·6 |
| 80 | 725±3·6 | 916±2·3 | 862±1·4 | 1090±7·1 | 918±3·7 | 986±3·4 | 1070±8·2 |
| 90 | 756±3·5 | 958±1·6 | 901±3·6 | 1134±6·3 | 960±4·6 | 1025±3·7 | 1115±6·7 |
| 100 | 780±2·5 | 985±3·0 | 952±4·2 | 1188±3·7 | 1004±1·5 | 1075±1·6 | 1170±7·4 |

*The absolute amount of water required for raising a crop.*—For all practical purposes it is not only the transpiration from the plants that is an all-important factor in irrigation, but the evaporation of water from the soil must also be taken into account in estimating the absolute amount of water required for successfully raising a crop. For determining the absolute quantity of water necessary to irrigate an acre of successful crop, therefore, the amount of evaporation from the soil and the plant with optimal condition of soil moisture at different stages of life-cycle, are determined. The evaporation per unit area of the soil is computed to an acre of land, while the water required for one gram of dry matter formation is also calculated for the total dry matter out-turn per acre. The total quantity is thus known by adding the water evaporated and transpired by the soil and plants respectively from an acre and finally expressed in terms of absolute irrigation in cu. ft. of water required for raising a successful crop. The details of the method of measuring transpiration and evaporation being covered in a previous contribution[11] from this Experiment Station, are not given once again.

TABLE VIII.

*The absolute amount of water required for transpiration, evaporation and the number and quantity of irrigation necessary for raising a successful crop*

| Crop | No. of plants per sq. yard | No. of plants in an acre | Dry weight per plant | Yield of an acre | Transpiration from plants of an acre | Evaporation from an acre field | Absolute amount of water required for irrigation and evaporation | Amount of water required for one irrigation for an acre field | No. of irrigation |
|---|---|---|---|---|---|---|---|---|---|
| | | | gm. | lb. | gm. | gm. | cu. ft. | cu. ft. | |
| Cereals at optimum soil moisture content 37% of water-holding capacity | | | | | | | | | |
| Triticum vulgare | 47 | 230026 | 8 | 4053 | 732402784 | 144517600 | 31003 | 11300 | 2-3 |
| Hordeum vulgare | 47 | 230026 | 6 | 3039 | 703878560 | 144517600 | 29995 | 11300 | 2-3 |
| Vegetables at optimum soil moisture content 43% of water-holding capacity | | | | | | | | | |
| Brassica botrytis | 2 | 11284 | 165 | 4101 | 924383000 | 874596800 | 62189 | 11300 | 5-6 |
| Brassica caulorapa | 3 | 14450 | 85 | 2705 | 799221250 | 795088000 | 56120 | 11300 | 5 |
| Beta vulgaris | 18 | 87965 | 26 | 5037 | 1189286800 | 795088000 | 70158 | 11300 | 5-6 |
| Brassica campestris | 18 | 87965 | 21 | 4068 | 1056635580 | 795088000 | 656168 | 11300 | 5-6 |
| Raphanus sativus | 18 | 87965 | 23 | 4456 | 1244264925 | 715579200 | 62291 | 11300 | 5 |

A reference to Table VIII indicates that *Beta vulgaris* yielding 5,037 lbs. of dry matter per acre require 70,158 cu. ft. of water for both transpiration and evaporation. Each irrigation should consist of 11,300 cu. ft. of water, the crop requiring six irrigations throughout the life-cycle. *Brassica campestris, Raphanus sativus, Brassica botrytis* and *Brassica caulorapa* each producing 4,068, 4,456, 4,101 and 2,705 lbs. respectively of dry matter per acre, require approximately 56,000 to 70,000 cu. ft. of water. In other words, for successfully raising these crops five to six irrigations, each of 11,300 cu. ft. of water are necessary.

*Triticum* and *Hordeum* which have been taken to represent the cereals produce approximately 4,000 and 3,000 lbs. of dry matter per acre and require for their successful growth about 30,000 cu. ft. of water. Calculating in terms of number of irrigation, two to three irrigations of 11,300 cu. ft. each, should suffice for obtaining good growth and yield.

The number of irrigations and the absolute quantity of water required for raising a successful crop, however, is subject to great modification and alteration in number and quantity both depending to a marked extent upon the rainfall, and the general climate and soil conditions of the locality. The suggestions above offered are mostly true for districts near about Benares and such other places where the soil and the climate have practically similar average characteristics.

*The critical periods of water requirement.*—The absolute amount of water required having been known, the question is, when to supply it with the maximum possibilities of growth and yield. To determine the critical periods in the life-cycle of the plants when the necessity of water is most felt, the weekly transpirational loss of water at optimal condition of soil moisture has been divided by the dry matter formed during that week. The weekly water requirement for the formation of one gram of dry material at a particular period of observation is calculated.

A survey of the data represented in Fig. 11 indicates that the experimental plants require more water during the seedling and pre-flowering stages. Necessity for water is felt, though to a lesser extent, towards the close of the life-cycle also. The critical periods of water requirement extend from seven days and more and differ for different plants, and for the same plant at different periods of the life-cycle.

In case of the vegetable crops, namely, *Beta vulgaris, Brassica caulorapa, Brassica botrytis, Raphanus sativus* and *Brassica compestris*, the necessity of water seems to be felt most between fourteen and twenty-one days in the young stage. The critical period extends for approximately twenty days

during the early stage when the plants are about 4"–6" in height and can be made good by supplying two irrigations at intervals of seven days each.
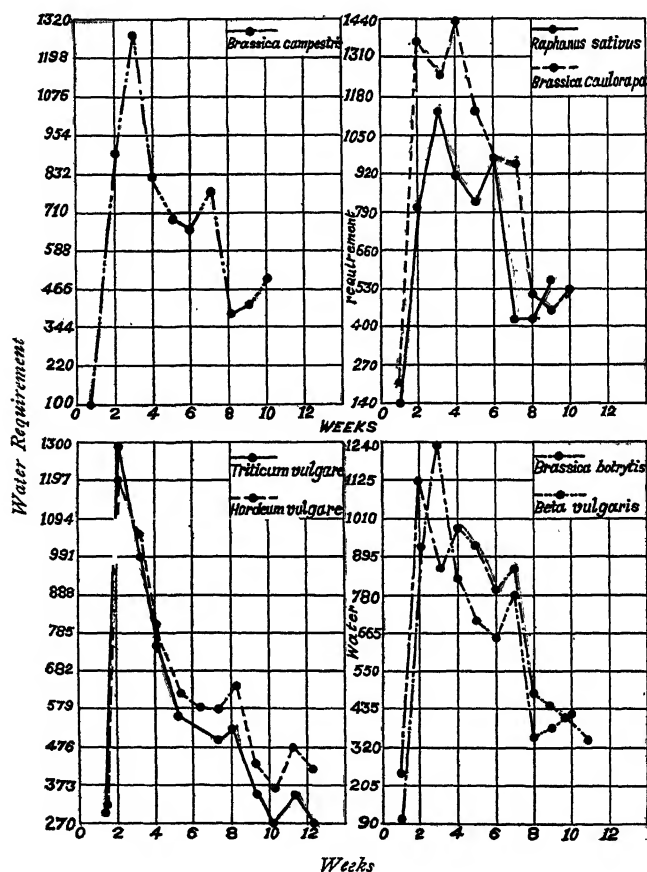


FIG. 11. Weekly water requirement of different crop plants.

The second critical period for the vegetable crops differs in different cases. *Brassica caulorapa* and *Brassica botrytis* have their critical stage when the plants are between twenty-five to thirty-five days old. This period coinciding with the active period of growth should be supplied with at least two irrigations in order to enable the plants to continue their growth efficiently as well as to overcome the effect of atmospheric drought.

In case of *Raphanus sativus, Beta vulgaris* and *Brassica campestris*, however, the second critical stage extends between forty and fifty days of the life-cycle and can be made good by supplying two irrigations, one at the beginning of this period while another towards its close.

TABLE IX.

*The critical periods of water requirement in vegetables grown under 43% of water-holding capacity.*

| Week | Water requirement | | | | |
|---|---|---|---|---|---|
| | *Brassica botrytis* | *Brassica caulorapa* | *Beta vulgaris* | *Brassica campestris* | *Raphanus sativus* |
| 1 | $239 \pm 2 \cdot 6$ | $230 \pm 3 \cdot 4$ | $98 \pm 3 \cdot 1$ | $104 \pm 3 \cdot 5$ | $142 \pm 2 \cdot 7$ |
| 2 | $1,131 \pm 4 \cdot 1$ | $1,369 \pm 2 \cdot 0$ | $923 \pm 4 \cdot 6$ | $908 \pm 4 \cdot 2$ | $809 \pm 1 \cdot 2$ |
| 3 | $853 \pm 3 \cdot 2$ | $1,246 \pm 3 \cdot 2$ | $1,237 \pm 5 \cdot 3$ | $1,302 \pm 6 \cdot 9$ | $1,137 \pm 5 \cdot 1$ |
| 4 | $985 \pm 4 \cdot 5$ | $1,437 \pm 4 \cdot 3$ | $834 \pm 5 \cdot 2$ | $831 \pm 5 \cdot 3$ | $917 \pm 4 \cdot 2$ |
| 5 | $934 \pm 5 \cdot 1$ | $1,140 \pm 5 \cdot 1$ | $701 \pm 4 \cdot 6$ | $718 \pm 7 \cdot 3$ | $824 \pm 2 \cdot 8$ |
| 6 | $798 \pm 5 \cdot 3$ | $985 \pm 5 \cdot 7$ | $656 \pm 2 \cdot 3$ | $678 \pm 7 \cdot 1$ | $982 \pm 2 \cdot 4$ |
| 7 | $860 \pm 3 \cdot 6$ | $963 \pm 4 \cdot 8$ | $782 \pm 1 \cdot 7$ | $791 \pm 3 \cdot 0$ | $432 \pm 3 \cdot 6$ |
| 8 | $475 \pm 2 \cdot 4$ | $520 \pm 2 \cdot 6$ | $349 \pm 3 \cdot 1$ | $405 \pm 2 \cdot 5$ | $438 \pm 4 \cdot 6$ |
| 9 | $438 \pm 1 \cdot 8$ | $468 \pm 3 \cdot 2$ | $384 \pm 2 \cdot 5$ | $430 \pm 1 \cdot 6$ | $576 \pm 3 \cdot 1$ |
| 10 | $399 \pm 5 \cdot 3$ | $537 \pm 1 \cdot 0$ | $410 \pm 3 \cdot 2$ | $520 \pm 2 \cdot 4$ | |
| 11 | $347 \pm 4 \cdot 6$ | | | | |

A reference to Table IX indicates that the third critical period is only found when the plants are sufficiently mature. Growth also has reached its maximal limit at this stage. This critical stage extends between sixty-three and seventy days. The water requirement being small, it can be overcome by supplying one irrigation when the plants are approximately sixty-five days old.

Thus, for vegetable crops, in general, five to six irrigations, two during the early stage when the plants are young, two during the adolescent period and one towards the pre-senescent stage should be productive of a successful crop with the minimum expenditure of labour and energy so far as irrigation is concerned.

In case of cereals also three critical stages of water requirement are to be located. These plants seem to require the largest quantity of water

between fifteen and twenty days after germination (*cf.* Table X). One irri-
gation at this critical stage is absolutely necessary. The second and third
critical stages are found when the plants are approximately fifty-five and
eighty days old. The water requirement during these periods is not so high
as in the early seedling stage and can be thus made good by supplying one
irrigation during each of these critical stages. The third irrigation towards
the seedling stage may be dispensed with if the soil is found to be rich in
moisture or if a shower of rain is available, since the requirement for water
is very small at this stage.

TABLE X.

*The critical periods of water requirement in cereals grown under
37% of water-holding capacity.*

| Week | Water requirement | |
|---|---|---|
| | *Triticum vulgare* | *Hordeum vulgare* |
| 1 | $336 \pm 2 \cdot 1$ | $315 \pm 3 \cdot 4$ |
| 2 | $1,300 \pm 4 \cdot 3$ | $1,214 \pm 4 \cdot 2$ |
| 3 | $1,000 \pm 5 \cdot 2$ | $1,064 \pm 6 \cdot 7$ |
| 4 | $748 \pm 5 \cdot 2$ | $774 \pm 5 \cdot 8$ |
| 5 | $570 \pm 7 \cdot 1$ | $638 \pm 5 \cdot 7$ |
| 6 | $542 \pm 6 \cdot 3$ | $600 \pm 3 \cdot 2$ |
| 7 | $507 \pm 3 \cdot 4$ | $588 \pm 1 \cdot 1$ |
| 8 | $535 \pm 1 \cdot 9$ | $652 \pm 4 \cdot 6$ |
| 9 | $365 \pm 3 \cdot 2$ | $443 \pm 4 \cdot 1$ |
| 10 | $276 \pm 3 \cdot 6$ | $370 \pm 2 \cdot 4$ |
| 11 | $353 \pm 2 \cdot 2$ | $480 \pm 3 \cdot 6$ |
| 12 | $283 \pm 4 \cdot 3$ | $425 \pm 2 \cdot 1$ |

The critical periods of water requirement in the life-cycle of the plant as
well as the absolute amount of irrigation required to raise a successful crop
are subject to fluctuations depending to a marked degree on the evaporating
conditions of the atmosphere and such other factors—internal and external,

which directly or indirectly increase the transpiratory loss of water. The observations herein recorded hold good for districts having the same ecological level of the atmosphere as Benares. For other places possessing different soil and atmospheric characteristics, considerable variations may be introduced, but well planned experiments in the light of the present contribution in these tracts may throw a flood of light on the question of irrigation in such quantities and at such stages when the supply of water will have the maximum possibilities of both growth and yield.

### Wilting Coefficient.

The importance of water in regulating the amount of transpiration as well as the water requirement of crop plants has been stressed in the previous pages. It has been shown that the moisture content of the soil is an important factor in determining the subsequent growth and final yield of plants and that plants belonging to different groups such as cereals and vegetables have different optimal requirement of soil moisture.

The question now arises as to whether the quantity of water under these optimal conditions, present either in available or non-available form, is totally taken up by the plants or else only a small percentage of this is useful from the point of view of the requirement of plant either for transpiration or growth purposes. Once this is known, the question would again arise from purely practical point of view, as to whether the available moisture under controlled conditions in a single type of soil would differ with the quality and texture of the soil particles, as also the type of the plant growing in such conditions.

In this connection it may be mentioned that the roots of the plants well established in the soil gradually reduce its water content which ultimately decrease to such a level that the plant is no longer able to absorb further quantity of the same and passes into a stage of wilting. Briggs and Shantz[2] have recognised two stages of wilting. The first, or incipient wilting, is defined as that stage of soil moisture when the plant has just entered into the wilting stage such that recuperation is possible after the supply of proper moisture conditions. When wilting has reached to such an extent that the plant does not recover from the wilting stage, even after the supply of suitable moisture, the plant is said to undergo permanent wilting. In arid localities where soil moisture is always a limiting factor in crop production, wilting, both incipient and permanent, is commonly observed. The stage of wilting is commonly found to differ for the same plant in different soils and for different plants growing in the same soil under similar stresses of evaporating power of atmosphere.

TABLE XI. *Relative wilting coefficient for different plants in loam soil.*

| Plants | Average* value | Probable error of average value |
|---|---|---|
| *Zea Mays* (Maize) .. | 8·0 | ± 0·004 |
| *Cyanodon dactylon* (Dub) .. | 7·7 | ± 0·006 |
| *Andropogon sorghum* (Jowar) .. | 7·8 | ± 0·009 |
| *Crotalaria juncea* (San hemp) .. | 7·98 | ± 0·006 |
| *Hibiscus esculantus* (Bhindi) .. | 7·75 | ± 0·004 |
| *Brassica oleracia* (Cabbage) .. | 7·65 | ± 0·010 |
| *Triticum vulgare* (Wheat) .. | 7·88 | ± 0·003 |
| *Brassica botrytis* (Cauli-flower) .. | 7·69 | ± 0·010 |

* Average of ten observations.

It is attempted in this series of contribution to investigate in the first place, the moisture content of a known soil at which, the plant undergoes permanent wilting. The wilting coefficient of the soil with respect to one plant being known, the next step lay in determining this coefficient in different soils and in the same soil with different plants. The determination of the wilting coefficient is made both by direct and indirect methods as detailed in the investigation of Briggs and Shantz.[4] The experiments are performed under typical conditions of sub-tropics where the moisture content of the soil is deficient for the major part of the year and where very little is known regarding the relation between the available moisture in the soil and the requirement of water by the plant. The study has been further extended to the common type soils available in the fields as also artificially prepared ones in which case the different percentages of salts and manures have been mixed to cause heterogeneity in texture and composition.

A perusal of Table XI indicating the relative wilting coefficients of plants in a loamy soil brings into prominence that plants of so varied a constitution as *Zea Mays, Cynadon dactylon, Brassica oleracea, Crotalaria juncea,* besides others, deplete the soil moisture to the same extent; in other words, the wilting coefficient of the soil remains practically the same irrespective of the type of the plant. These results are in accordance with the experimental findings of Briggs and Shantz[2] who have also observed more or less similar phenomenon in case of sandy soil in which they grew the plants.

## TABLE XII.

| Soil type | Comparison of the observed wilting coefficient with that found by computation from moisture-holding capacity of the soil | | The relation of the wilting coefficient to the hygroscopic coefficient of the soil | | The relation of the wilting coefficient to the moisture equivalent of the soil | | The relation of the wilting coefficient to the moisture-holding capacity of the soil | |
|---|---|---|---|---|---|---|---|---|
| | Wilting coefficient by computation | Wilting coefficient by observation | Hygroscopic coefficient | Wilting coefficient — Average of five determinations | Moisture equivalent | Wilting coefficient — Average of five determinations | Moisture-holding capacity | Wilting coefficient — Average of five determinations |
| Sandy soil .. | 2·2 | 1·9 | 1·50 | 2·20 | 4·1 | 2·2 | 27·6 | 2·20 |
| 20% NaNO₃ with loam soil .. | 4·5 | 4·8 | 3·10 | 4·47 | 8·4 | 4·5 | 34·2 | 4·50 |
| Green manured soil... | 6·3 | 6·7 | 4·30 | 6·32 | 11·34 | 6·16 | 39·5 | 6·30 |
| 20% Superphosphate with loam soil .. | 6·5 | 6·9 | 4·50 | 6·60 | 11·70 | 6·35 | 40·0 | 6·50 |
| Loam soil .. .. | 7·2 | 7·8 | 4·90 | 7·20 | 13·10 | 7·11 | 41·87 | 7·20 |
| 20% Niciphos with loam soil .. | 10·3 | 11·0 | 7·10 | 10·40 | 18·60 | 10·10 | 51·00 | 10·30 |
| 20% Lime with loam soil .. .. | 12·2 | 13·0 | 8·20 | 12·00 | 22·60 | 12·33 | 56·50 | 12·20 |
| Clay soil .. .. | 13·1 | 14·2 | 8·84 | 12·94 | 23·00 | 12·50 | 59·50 | 13·10 |

In the second series, *Andropogan sorghum* has been selected as the representative plant and grown in the different types of experimental soils. In these series the wilting coefficient of the types of soils is determined by the method adopted in the first one. A survey of Table XI indicates that the observed wilting coefficient is minimum in case of sandy while maximum in the case of clay. The other types lie midway between the two. There is no definite gradation with respect to either the quantity of organic matter, salts or lime. In general, the smaller the particles, the greater seems to be the wilting coefficient. This is true for clay and sand, but cannot hold good for other soil types.

When compared with wilting coefficient determined on the basis of moisture equivalent, hygroscopic coefficient, and moisture holding capacity, the different types of soils exhibit practically similar observed wilting coefficient, the range of deviation of the computed values from those of the observed, remaining more or less constant (*cf.* Table XII).

*Summary and Conclusions.*

In the present contribution the amount of water lost from the aerial parts of a number of vegetable crops and a few cereals is studied at successive stages of their life-cycle. The transpiration rate is analysed with special reference to the growth and water requirement of the experimental plants.

Special stress is laid in studying the transpiration rate under varying conditions of soil moisture, the critical periods of water requirement and the absolute amount of irrigation required for optimal growth and yield of plants.

The evaporation of water from the leaf surface as well as a shallow water pan is studied by loss-in-weight method and care is taken to see that the plants grew under as identical conditions of environmental factors as possible. All the factors except the one under consideration, namely, the water-supply, are maintained above their optimal level such that the variations in subsequent growth of plants are interpretable in terms of this variable alone.

The increase in the percentage of water results in a characteristic rise in the transpiration rate of the leaves, the greater the moisture content of the soil the greater is the evaporation of water from the plants. This is characteristically noted not only in the case of one plant but all the representative types studied. In every case the transpiration increases till 80 per cent of water-holding capacity of the soil, further increase in moisture saturation above this limit results in no appreciable increase in the transpiratory loss of water.

It is clear that optimal growth in cereals may be secured at percentages between twenty-two and forty and in the case of vegetables at a soil moisture

content of 37 to 55 per cent of water-holding capacity of soil. Below and above these critical values growth seems to be greatly determined by the percentage of soil moisture.

In case of cereals the minimum point for water requirement is located in the vicinity of 37 per cent of water-holding capacity whereas for the vegetables the minimum is found to be at 45 per cent of water-holding capacity. There is a fall in water requirement with increase in the moisture content till 37 per cent in case of cereals and 45 per cent in vegetables and a gradual rise of requirement for water in cereals as well as vegetables above these optima.

*Beta vulgaris* yielding 5,037 lbs. of dry matter per acre requires 70,158 cu. ft. of water for transpiration and evaporation each irrigation requiring on an average 11,300 cu. ft. of water supplied six times during the life-cycle.

*Brassica campestris, Raphanus sativus, Brassica botrytis* and *Brassica caulorapa,* each producing 4,068, 4,456, 4,101, and 2,705 lbs. respectively of dry matter per acre require approximately 56,000–70,000 cu. ft. of water. In other words, for successfully raising these crops five to six irrigations, each of 13,000 cu. ft. of water are necessary.

*Triticum* and *Hordeum* produce approximately 4,000 and 3,000 lbs. of dry matter per acre and require for their successful growth about 30,000 cu. ft. of water. Thus these crops require two to three irrigations of 11,300 cu. ft. each for obtaining good growth and yield.

The plants have either two or three critical periods when they require the largest amount of water. These periods cover different number of days in different crops but always happen to be located in seedling, pre-flowering, and ripening stages.

The observed wilting coefficient for a definite soil is more or less constant being independent, to a great extent, of the nature of the plant growing in it.

The wilting coefficient calculated on the basis of moisture holding capacity, moisture equivalent, and the hygroscopic coefficient, agree fairly with the observed values.

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# *HAEMOGREGARINA THYRSOIDEAE* N. SP., PARASITE OF THE INDIAN EEL *THYRSOIDEA MACRURUS* BLEEKER.

By Col. I. Froilano de Mello

AND

Miss Ciriaca Vales.

*(Nova Gôa.)*

The fish was identified by Dr. Baini Prashad from Calcutta, to whom our best thanks.

It seems that up-to-date only one hæmogregarine has been described in Indian fishes (*Hg. sp.* Plimmer 1914 par. of *Trichogaster fasciatus*).

Hæmogregarines, so commonly found in marine fishes, occur less frequently in fresh-water fish; among the eels, for example, the only species found harbouring these parasites, is *Anguilla vulgaris* with *Hg. lignieresi* Laveran, 1906, South America and *Hg. bettencourti* Franca, 1908, Portugal.

Our eel was collected in Nova Gôa in a tank of fresh-water, in connection however with the currents of the Mandovy river. Only blood smears were examined and they showed a rather scanty parasitism by hæmogregarines, some specimens of which are figured in the illustration.

The youngest form is ovoid with a conspicuous nucleus and the protoplasm light blue at Romanowsky's stain. When the parasite is grown up, its protoplasm shows an irregular vacuolisation, specially in the centre.

The nucleus of the parasite occupies generally a central position. It is composed of a vesicular amount of chromatin, often divided in two, more or less irregular masses, representing probably a beginning of division (Fig. 8). The nuclear membrane is not distinct. Moreover in the nuclear mass there are some minute granules, taking the same chromatic tone and which seem to represent volutine granulations.

If this is the normal position and appearance of the nucleus we have often found other types which we will describe : the chromatin reduced to two very minute granules, centrally situated (Fig. 3) ; the nucleus evidently situated in one of the poles and composed of two masses (Fig. 5) ; polar nucleus and chromatoid granules scattered (Fig. 7) ; two nuclear masses, one in each pole (Figs. 1, 4, 6).

No smears of organs were unhappily examined.

.The characters above described are so different from the hæmogregarines of *Anguilla vulgaris*, that we consider our species a new one which will be named according to the genus of the parasitised eel.

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and Miss Ciriaca Vales.

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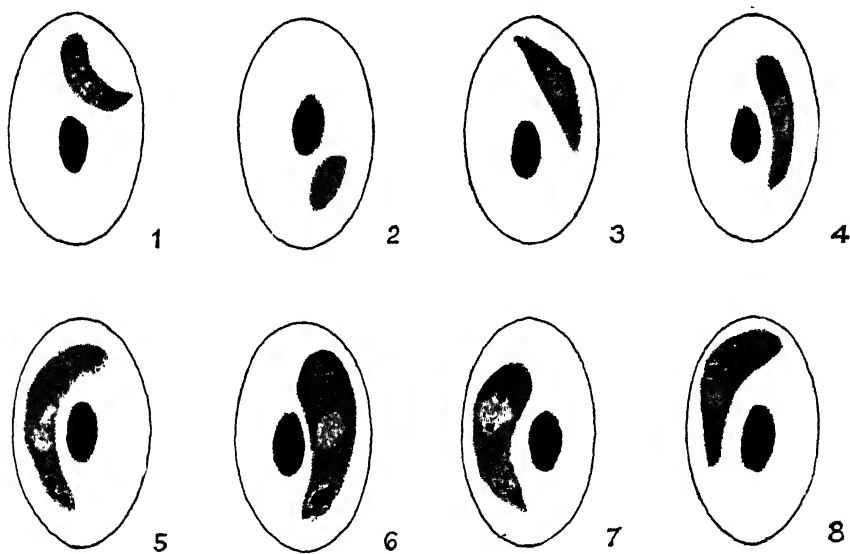
# A SHORT NOTE ON AN INDIAN VARIETY OF *SPHAEROPLEA ANNULINA* (ROTH.) AGARDH, VAR. *MULTISERIATA*, VAR. NOV.

BY M. S. RANDHAWA, M.Sc., I.C.S.

*(Saharanpur.)*

A VARIETY of *Sphæroplea annulina* (Roth.) Agardh was collected by the author from many ponds during the months of March and April in 1930 from Hoshiarpore, Jullundar and Amritsar. During March the filaments become yellowish-green in colour, and on examination under the microscope numerous green ova may be seen in most of them. By the end of April nearly all the filaments show red oospores, and they occur in such large numbers that drying banks of most ponds present a crimson-red appearance.

Under the microscope a number of annular chloroplasts may be seen in each cœnocyte. Under the high power the annular bands of chloroplasts show bridge-like interconnections (Fig. 1), the whole presenting the appearance of a reticulum as in *S. africana* Fritsch. A number of pyrenoids may be seen arranged in a row on each chloroplast. One to two nuclei may also be seen in the cytoplasm.

The septa are homogeneous ingrowths of the longitudinal walls (Fig. 2) as in typical filaments of *S. annulina* (Roth.) Agardh, and the cœnocytes do not intercommunicate by means of any pores. The cœnocytes are 60–80μ in diameter being somewhat broader than those reported from Europe.

## Sexual Reproduction.

The remarkable feature of the alga is its oogonia which are formed from the ordinary cœnocytes without any change of form. The protoplasm of the cœnocytes becomes cleft into numerous green ova, which in the present variety may be seen arranged in three to five longitudinal rows (Fig. 3). It is due to this that the author has named this variety of *S. annulina* (Roth.) Agardh as Var. Nov. *multiseriata*. Such a multiserial arrangement of ova and oospores is seen only in *S. africana* Fritsch, and Klebahn's figure of a segment of an oogonium of *S. annulina* (Roth.) Agardh as reproduced by Fritsch in his *The Structure and Reproduction of the Algæ*, shows only a single row of ova. The ova in the present variety are deep green in colour and have 1–3 pyrenoids in each (Fig. 3).

405

B4

Apertures for the entry of the sperms may be seen in the walls of the oogonia (Fig. 4, *o*).  The ova are 17–27$\mu$ in diameter.

The young oospores are green in colour and are often found enclosed in a thin hyaline membrane (Figs. 5 and 6), which is later shed, and such discarded membranes  may  be  found  in  large  numbers  alongside  of  the  oospores
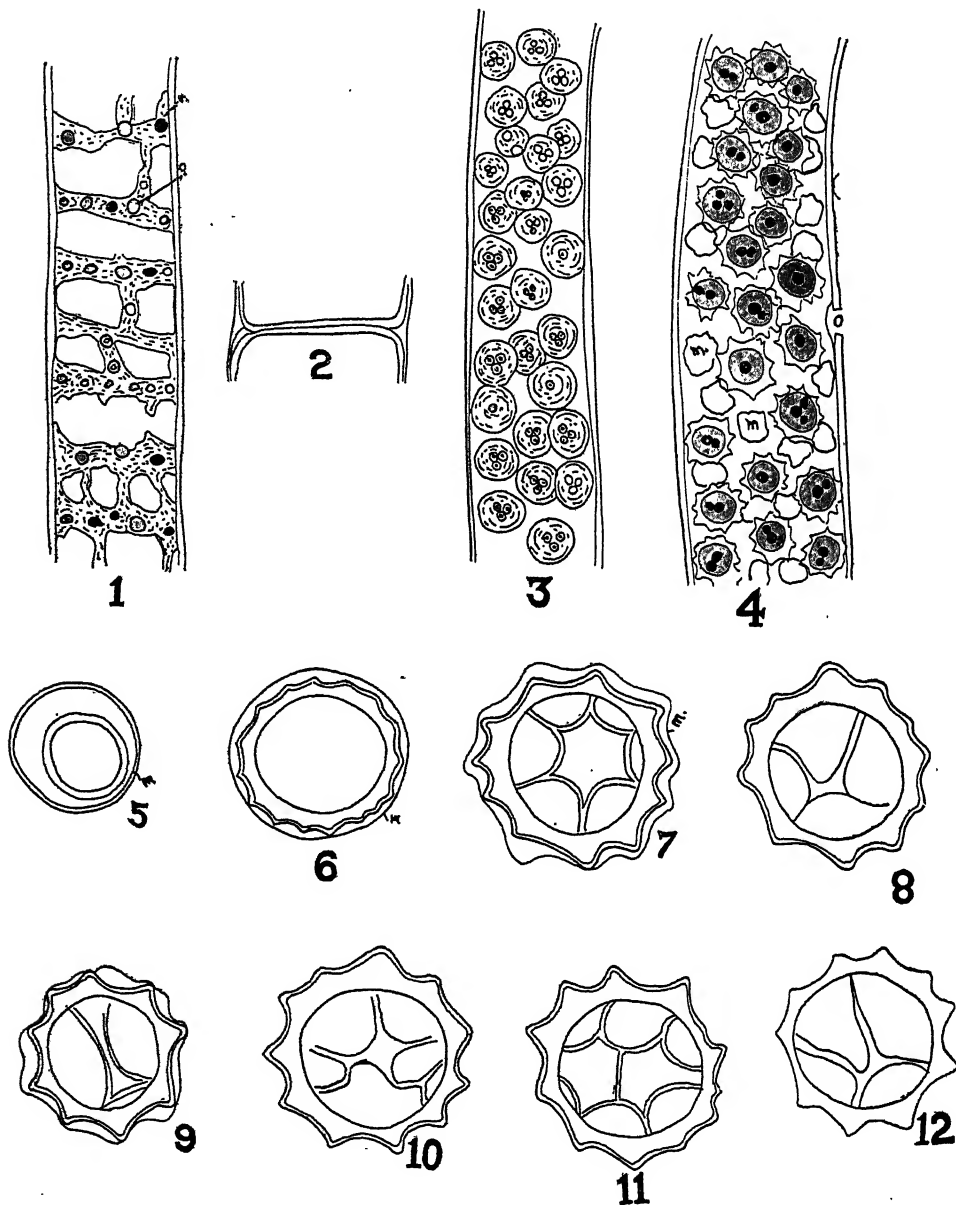
(Fig. 4, *m.*). The oospores are spherical in shape, and their outer hyaline wall is produced into 10–15 blunt spines. The number of spines in the present variety is fewer as compared with *S. annulina* (Roth.) Agardh as figured by Fritsch and Rich.[3] Under an oil immersion lens, the surface of the oospores shows distinct aereolations (Figs. 7, 8, 9, 10, 11 and 12).

This form differs from the type in the disposition of its ova and oospores in 3–5 rows, fewer number of teeth on the oospore wall and the slightly broader size of its cœnocytes. Hence I have named it as Var. *multiseriata* var. nov. This is also, so far as I know, the first report of this alga from India.

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## EXPLANATION OF FIGURES.

Fig. 1.—Shows a part of a cœnocyte with chloroplasts, pyrenoids (*p*) and nuclei (*n*). $\times$ 420.

Fig. 2.—Shows a Septum. $\times$ 420.

Fig. 3.—Shows a part of an oogonium with three rows of ova. $\times$ 420.

Fig. 4.—Shows a part of a mature oogonium with oospores, discarded membranes of oospores (*m*), and an opening (*o*) in the wall of the oogonium for the entry of the sperms. $\times$ 420.

Fig. 5.—Shows a young oospore enclosed in a primary membrane (*m*). $\times$ 1260.

Figs. 6 & 7.—Show oospores enclosed in primary membranes. $\times$ 1260.

Figs. 8 to 12.—Show ripe oospores, the teeth-like projection of their outer wall, and aereolations on their outer surfaces. $\times$ 1260.

# A NEW SPECIES OF *CYLINDROCAPSA* FROM INDIA.

## Cylindrocapsa oedogonioides sp. nov.

BY M. S. RANDHAWA, M.Sc., I.C.S.

*(Saharanpur.)*

Received September 4, 1936.

(Communicated by Dr. H. Chaudhuri, M.A., PH.D.)

THIS very rare alga was found entangled in the filaments of a species of *Oedogonium*, which was growing epiphytically on the blades of *Typha* plants in Shahniwala Tank at Dasuya, Punjab, during the months of March and April, 1930 and 1931. During March only sterile filaments were seen, but by the last week of April, some filaments developed oogonia, antheridia, and oospores. So far as the author knows there has been no record of any species of the rather uncommon genus *Cylindrocapsa* from India. Possibly this is due to the habit of the alga, for even where it occurs it is found in such a scattered condition that after a long search under the microscope one may be lucky enough to spot a filament or so.

The filaments are unbranched and consist of a single row of more or less sub-rectangular cells, which are enclosed within a lamellose sheath, as in *Cylindrocapsa conferta* West. But the cells of this alga differ from those of *C. conferta* in having two small pyrenoids at the opposite ends of the cells (Figs. 1 and 2), instead of a single massive pyrenoid as in the former. There is a single massive chloroplast, which is parietal in position, and presents a more or less granular appearance. In most of the cells a dumb-bell shaped nucleus may be seen in the middle surrounded by two pyrenoids at the sides (Figs. 2 and 4). Vegetative cells are 18–20 $\mu$ broad, and 12–28 $\mu$ long, being considerably narrower than those of *C. conferta*.

### Reproduction.

This alga is characterised by the presence of a well-developed oogamy. Of the species so far known, sexual reproduction has been worked out only in *C. involuta* Reinsch. In the present form the method of reproduction and the sex organs differ from that of *Cylindrocapsa involuta* in many details. The filaments may be monœcious; the antheridia and oogonia developing in the same filament, or diœcious, in which case the male and female sex organs develop on different filaments.

*Antheridia.*—The antheridia are produced by division of certain cells, which may be distinguished from the normal vegetative cells by their much

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smaller size (Figs. 2*a* and 5*a*).   In one filament rows of empty cells were seen alternating with rows of enlarged cells (Fig. 4).   Probably these represent antheridial cells out of which sperms have escaped.
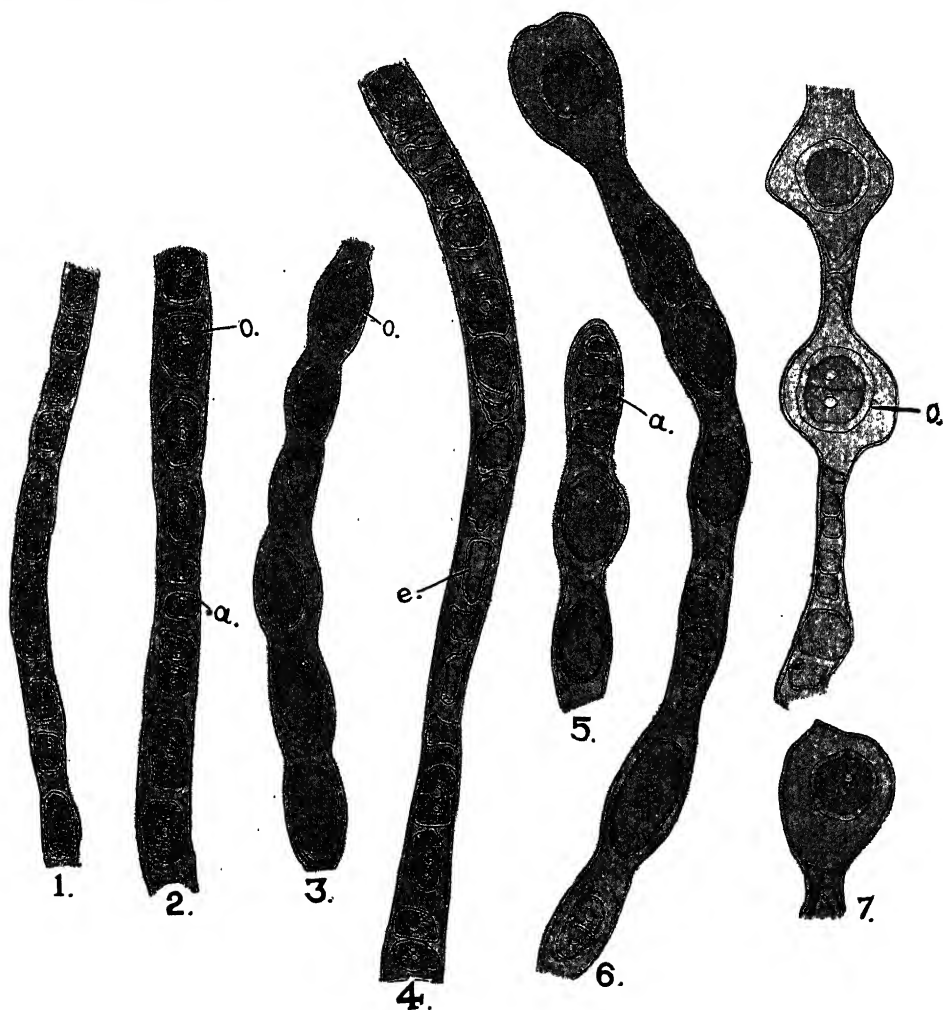


*Oogonia.*—The oogonia develop from ordinary vegetative cells, which become oval in shape, and increase considerably in size.   Sometimes whole rows of cells in some filaments become converted into oogonia (Fig. 3), and such filaments show constrictions in the sheath, which makes the alga look like an enlarged *Anabæna*.   The oogonia are 44–56 $\mu$ broad and 60–70 $\mu$ long.   No lateral pore was observed in any of the oogonia.   There is a single ovum in each oogonium, which is produced by the contraction of the protoplasm, and this results in a considerable empty space in the oogonia.   The

oospores are 28 $\mu$ in diameter, being considerably smaller as compared with those of *C. involuta*, and are surrounded by a thick hyaline wall (Figs. 6 and 7). In one instance the oospore was seen divided into two cells (Fig. 7, *o*). The filaments with mature oogonia, containing oospores, do not look very much different from the filaments of *Oedogonium*, and hence the specific name *œdogonioides*. The lateral sides of the mature oogonia do not show any lamellation as in *C. involuta*.

### *Cylindrocapsa œdogonioides*, sp. nov.

Vegetative cells 18–20 $\mu$ broad, 12–28 $\mu$ long, rectangular or sub-rectangular in shape, enclosed in a lamellose sheath. A single massive chloroplast parietal in position, with two small pyrenoids in each. Oogonia 44–56 $\mu$ broad, 60–70 $\mu$ long, inflated, with no lamellæ at the sides. Oospores 28 $\mu$ broad with a thick mucilaginous hyaline sheath.

*Habit.*—Found mixed with filaments of a species of *Oedogonium* growing epiphytically on *Typha* blades in Shahniwala Tank, Dasuya, district Hoshiarpore, Punjab, during March and April, 1930 and 1931.

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### EXPLANATION OF FIGURES.

FIGS. 1–7.—*Cylindrocapsa œdogonioides*, sp. nov.

FIG. 1.—A vegetative filament showing cells with two pyrenoids in each.   × 660.

FIG. 2.—A filament showing active division of some cells developing later into antheridia (*a*), and enlargement of other cells developing into oogonia (*o*). × 660.

FIG. 3.—A filament showing a chain of female cells which later develop into oogonia. × 666.

FIG. 4.—A filament showing some empty cells.   × 660.

FIG. 5.—A portion of a filament showing antheridial cells (*a*), and two oogonia.   × 660.

FIG. 6.—A mature filament showing an oogonium with an oospore.   × 660.

FIG. 7.—A filament showing three oogonia with oospores.   × 660.

# STUDIES IN *DOLICHOS LABLAB* (ROXB.) AND (L.)— THE INDIAN FIELD AND GARDEN BEAN. III.

BY G. N. RANGASWAMI AYYANGAR, B.A., I.A.S.,

*Agricultural Research Institute, Coimbatore,*

K. KUNHI KRISHNAN NAMBIAR, B.SC., AG.

AND

P. KRISHNASWAMY, B.SC., AG.,

*Millets Breeding Station, Coimbatore.*

*Seed Coat Colour and Plant Purple Pigment—Their Affinities and Inheritance.*

In *Dolichos lablab* (Roxb. and L.) varietal distinctions can be made on the basis of seed coat colour and plant purple pigmentation. Plants may or may not have purple pigment on them. When they do not have purple pigment, their vegetative parts are green throughout and they bear white flowers. Purple pigmented plants differ in the depth and distribution of the pigment in their vegetative and floral parts. On the basis of these differences eight types can be made out. They are described below.

## 1. Pigment Types.

I. *G. Type. The Green Throughout Type : Vegetative parts*—green. *Calyx*—green. *Corolla*—white. *Pods*—green.

II. *P. Type* 1. *The Pink Wings Type* : This type represents the lowest rung in the pigmentation series. *Vegetative parts*—green. *Calyx*—green. *Corolla*—Wing petals alone pink. *Pod*—green.

The pink colour in the wing petals is of a very evanescent nature. It appears close on the opening of the flower and disappears after about a day. There is thus a chance of this type being mistaken for the Green Throughout Type. The pink colour that has become invisible is found to reappear on the application of any acid. Wing petals in fairly mature buds and in flowers that are not too much faded respond to this test. Acetic acid has been found to be a convenient reagent and has therefore been made use of in segregations involving the elusive Pink Wings Type.

III. *P. Type* 2. *The Pink Ridge—Chocolate Seed Type :* *Vegetative parts*—faint purple in stray leaf axils. *Calyx*—faint purple. *Corolla*—The auricular ridge at the base of the standard is pink in colour, the standard and wings remaining white. *Pod*—usually green, occasionally tinged with faint purple on the sutures in a few garden varieties.

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IV. *P. Type 3. The Purple Flower—Buff Seed Type : Vegetative parts*—green. *Calyx*—green. *Corolla*—standard and wings, purple. *Pod*—green.

V. *P. Type 4. The Purple Axil—Purple Flower Type : Leaf axil*—purple. *Internode*—green. *Calyx*—purple. *Corolla*—purple. *Pod*—green.

VI. *P. Type 5. The Purple Internode Type : Internode*—purple wash. *Calyx*—purple. *Corolla*—purple. *Pod sutures*—tinged with purple.

VII. *P. Type 6. The Garden Purple Type* : Unlike the types described above, this type and the next (P. Type 7) occur in the garden pole varieties only. *Internodes*—completely coloured purple. *Petioles*—purple. *Leaf veins*—purple. *Pulvinus*—generally green, sometimes with a slight purple wash. *Pulvinule*—green. *Calyx*—purple. *Corolla*—purple. *Pod*—purple all along the edges with a purple wash in-between.

VIII. *P. Type 7. The All Purple Type* : In this type the whole pod is coloured purple. Both the pulvinus and the pulvinule are purple. The leaves are tinged with a purple colour giving the whole vine a sooty look.

Of the above types, 3 and 4 have been noted so far to occur in the field varieties only, and 6 and 7 in the garden pole varieties only.

A tabular description of the distinguishing features of the 8 types is given in the next page (Table I).

It will be noticed that P. Types 2, 4, 5, 6 and 7 have purple in the calyx going with purple in the leaf axil. Of these, P. Type 2 differs from the rest in having white flowers with pink ridge. In P. Type 3, the flower is purple, but the calyx (together with the axil) is green.

TABLE I.

*Plant Purple Pigmentation Types.*

| Pigmentation types | | Pigmented parts | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Axil | Internode | Petiole | Pulvinus | Pluvinule | Leaf veins | Leaf interveins | Calyx | Corolla | Pod |
| G. Type | G | G | G | G | G | G | G | G | White | G |
| P. Type 1 | " | " | " | " | " | " | " | " | Pink wings | " (Faint P margin in some garden varieties) |
| " 2 | Faint P occ. | " | " | " | " | " | " | Faint P occ. | Pink ridge | |
| " 3 | G | G (Sl. P wash occ.) | " | " | " | " | " | G | P | " |
| " 4 | P | " | " | " | " | " | " | P | " | " |
| " 5 | " | P Wash | P Wash | Sl. P Wash | " | P in principal veins | " | " | " | P margin |
| " 6 | " | P | P | " | " | P | " | " | " | P wash |
| " 7 | " | " | " | P | P | " | P | " | " | P |

G = Green ;     P = Purple ;     Occ. = occasionally ;     Sl. = Slight.

## 2. Seedlings.

In seedlings these differences in the adult plants find a condensed expression as the following grouping will show.   The  differences can be made out when the seedlings are about a month old.

|  | Adult | | Seedling |
|---|---|---|---|
| G. Type | | | Green. |
| P. | ,,  1 | | |
| P. | ,,  3 | | |
| P. | ,,  2 | | Faint purple in stray leaf axils. |
| P. | ,,  4 | | Good purple in leaf axil. |
| P. | ,,  5 | | Internode purple wash. |
| P. | ,,  6 | | Internode purple, veins purple. |
| P. | ,,  7 | | Internode purple, veins purple, pulvinus and pulvinule purple. |

These seedling differences help in the quick determination of certain aspects of simple segregation in the pursuit of the inheritance of certain characters in this long duration pulse.

A tabular description of the seedling groups is given below.

TABLE II.

*Purple Pigmentation in Seedlings.   (One Month Old.)*

| Pigmentation types | Pigmented parts | | | | | |
|---|---|---|---|---|---|---|
| | Axil | Internode | Petiole | Pulvinus | Pulvinule | Leaf veins |
| G. Type<br>P. Type 1, 3 | G | G | G | G | G | G |
| P. Type 2 | Faint P stray | ,, | ,, | ,, | ,, | ,, |
| ,,  4 | P | ,, | ,, | ,, | ,, | ,, |
| ,,  5 | ,, | P wash | P wash | ,, | ,, | P in principal veins |
| ,,  6 | ,, | P | P | Sl. P wash | ,, | P |
| ,,  7 | ,, | ,, | ,, | P | P | ,, |

N.B.—The stray faint purple in the P Type 2 seedling is often very difficult to make out owing to the few axils in the seedling.

It will be noticed that the differences in the purple pigmentation of the vegetative parts in the pigmented types may be made out in seedlings one month old.

### 3.  Seed Coat Colours.

It was mentioned in a previous paper (G. N. Rangaswami Ayyangar and K. Kunhi Krishnan Nambiar, 1935) that the seed coat colours occurring

in *lablab* are Black, Chocolate, Khaki and Buff ; and that in Black, Chocolate, and Khaki, the colour may be manifested over the whole of the seed coat or be localised. There are several kinds of these localisations existing as distinct heritable types. It has been found that the relation between plant purple pigment and seed coat colour is independent of wholeness or localisation in the seed coat. Hence, for the purposes of the present paper, when the seed coat colours Black, Chocolate and Khaki are referred to, their localised manifestations are also included. Thus the Bf factor has been left out so as not to complex the major issues, as whether whole or micropylar, the colour involved is the same, and its affinities to plant pigment similar. The Buff colour always exists in wholeness.

It was also shown that a factor K producing the Khaki colour in the seed coat is also present in Chocolate and Black, and that this K factor is absent in Buff.

### 4. *Seed Coat Colour—Plant Purple Pigment, Affinities.*

The Black seed coat occurs in P. Type 7, P. Type 6, P. Type 5 and P. Type 4, and these 4 types give Black seeds only.

The Chocolate seed coat occurs always with P type 2 and P type 2 has so far given no other seed coat colour.

The Khaki seed coat may occur with either P. Type 1 or the G. Type.

The Buff seed coat occurs with any of 3 classes, P. Type 3, P Type 1 and the G. Type. P. Type 3 gives Buff seeds only.

These relations are graphically presented below :—

| Seed Coat Colour | Plant Pigmentation Type |
|---|---|

```
BUFF ───────────────────►G. type 1
          ╳
KHAKI ───────────────────►P. type 1
          ╲
CHOCOLATE ─────────────      ,,   2

                              ,,   3

                              ,,   4

                         ╱    ,,   5
BLACK ◄──────────────
                         ╲    ,,   6

                              ,,   7
```
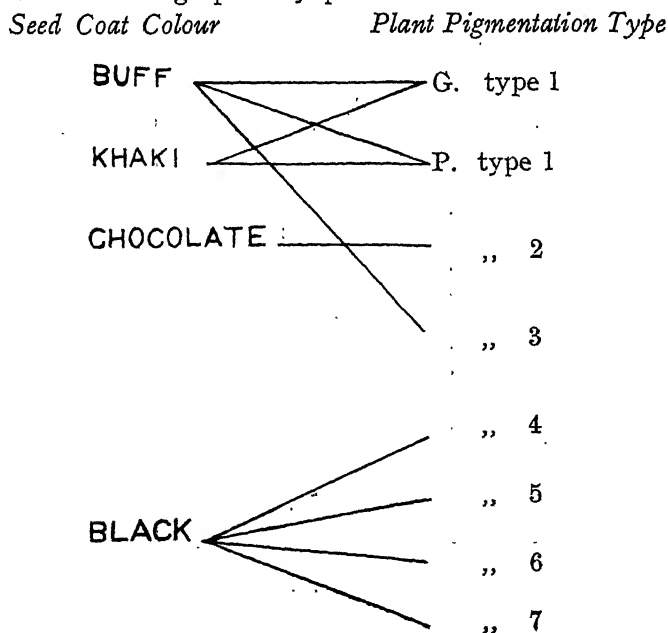
We have thus ten combinations of seed coat colour and plant purple pigment. These are distinct and breed true.

The eight plant pigment types and the related seed coat colours are illustrated in the Plate.

### 5. Inheritance of Seed Coat Colour and Plant Purple Pigmentation.

*Previous work.*—The only work on *lablab* seed coat colour and plant pigment affinities is by Harland (1920). He dealt with three types, *viz.*, (i) white flowers, white seeds, green plant body; (ii) white flowers, purplish brown seeds, purple stipular hairs; (iii) purple flowers, black seeds, purple nodes. A cross made between types (i) and (ii) gave $F_1$ plants of type (iii) and the $F_2$ segregated in the ratio of 9 : 3 : 4 of types (iii), (ii) and (i) respectively. The "white" flowers of Harland were obviously 'white" flowers with pink wings and pink ridge.

The order of dominance in seed coat colours is Black, Chocolate, Khaki, Buff. Black is dominant to Chocolate, Khaki and Buff. Chocolate is dominant to Khaki and Buff and recessive to Black. Khaki is dominant to Buff and recessive to Black and Chocolate. Buff is recessive to Black, Chocolate and Khaki. The exact relationship of these colours, each with the other, will be made clear when they are considered along with the plant purple pigmentation types occurring in each. We now proceed to examine the mode of inheritance of the various groups.

TABLE III.

*Pure for G Type.*

*Buff Seed (kk) × Khaki Seed (KK). $F_1$—Khaki Seed (Kk).*

| $F_2$ Family No. | Khaki Seed | Buff Seed |
|---|---|---|
| D.L.     120 | 16 | 4 |
| ,,     136 | 13 | 4 |
| ,,     137 | 11 | 4 |
| ,,     545 | 149 | 43 |
| ,,     546 | 132 | 38 |
| ,,     547 | 112 | 32 |
| ,,     548 | 123 | 37 |
| ,,     550 | 132 | 49 |
| ,,     1098 | 77 | 31 |
| Total | 765 | 242 |
| Expected, 3 : 1 ratio | 755·25 | 251·75 |

P > 0·30

The G. Type (Green Throughout Type) gives two kinds of seed coats Khaki and Buff.   In a previous article (G. N. Rangaswami Ayyangar and K. Kunhi Krishnan Nambiar, 1935) it has been noted that a Buff seed coat colour and absence of colour at the micropylar zone are the characteristics of the Buff cloured seed.   A factor K exists in all the three colours Khaki, Chocolate and Black and is absent in Buff.   This factor K brings about the colour Khaki (the basic colour for Chocolate and Black).   Along with the production of Khaki colour this K colours the micropylar zone.   Buff with the factor K gives Khaki.   Segragations for K and k are given in Table III.

P. Type 1 (The Pink Wings Type) also gives the two seed coats Khaki and Buff.   Segregations for K and k in this type are given in Table IV.

<center>TABLE IV.</center>

<center>*Pure for P. Type 1.*</center>

<center>*Buff Seed (kk) × Khaki Seed (KK). $F_1$—Khaki Seed (Kk).*</center>

| $F_2$ Family No. | | Khaki Seed | Buff Seed |
|---|---|---|---|
| D.L. | 114 .. | 180 | 57 |
| ,, | 497 .. | 45 | 13 |
| ,, | 498 .. | 17 | 6 |
| ,, | 499 .. | 24 | 8 |
| ,, | 508 .. | 99 | 27 |
| ,, | 510 .. | · 83 | 22 |
| ,, | 511 .. | 77 | 33 |
| ,, | 1026 .. | 78 | 21 |
| ,, | 1027 .. | 91 | 29 |
| ,, | 1028 .. | 70 | 26 |
| | Total .. | 764 | 242 |
| Expected, 3 : 1 ratio | .. | 754·5 | 251·5 |

<center>$P > 0.30$</center>

A factor P acting independently of the factor K is responsible for the production of P. Type 1 from the G. Type.   Segregations for the P factor are given in Tables V and VI, in the seed coats Buff and Khaki respectively.

TABLE V.

*Pure for Buff Seed (kk).*

*G. Type (pp) × P. Type 1 (PP). F₁—P. Type 1 (Pp).*

| F₂ Family No. | | P Type 1 | G Type |
|---|---|---|---|
| D.L. 139 | .. | 15 | 3 |
| ,, 744 | .. | 5 | 2 |
| Total .. | | 20 | 5 |
| Expected, 3 : 1 ratio .. | | 18·75 | 6·25 |

P > 0·50

TABLE VI.

*Pure for Khaki Seed (KK).*

*G. Type (pp) × P. Type 1 (PP). F₁—P. Type 1 (Pp).*

| F₂ Family No. | | P. Type 1 | G. Type |
|---|---|---|---|
| D.L. 142 | .. | 13 | 5 |
| ,, 960 | .. | 25 | 6 |
| ,, 962 | .. | 32 | 10 |
| ,, 1000 | .. | 37 | 11 |
| ,, 1001 | .. | 52 | 19 |
| Total .. | | 159 | 51 |
| Expected, 3 : 1 ratio .. | | 157·5 | 52·5 |

P > 0·80

Dihybrid segregations for both K and P are given in Table VII.

TABLE VII.

*G. Type, Buff Seed (kk pp) × P. Type 1, Khaki Seed (KK PP).*

*F₁—P. Type 1, Khaki Seed (Kk Pp).*

| F₂ Family No. | | Khaki Seed | | Buff Seed | |
|---|---|---|---|---|---|
| | | P. Type 1 | G. Type | P. Type 1 | G. Type |
| D.L. 113 | .. | 86 | 32 | 25 | 7 |
| ,, 1099 | .. | 132 | 41 | 36 | 12 |
| ,, 1106 | .. | 101 | 29 | 24 | 14 |
| Total .. | | 319 | 102 | 85 | 33 |
| Expected, 9 : 3 : 3 : 1 ratio .. | | 303·21 | 101·07 | 101·07 | 33·69 |

P > 0·20

In P. Type 2, the Pink Ridge and the Chocolate seed coat always occur together. It is hence called The Pink Ridge—Chocolate Seed Type. A factor Ch with the factor K produces this type (G. N. Rangaswami Ayyangar and K. Kunhi Krishnan Nambiar, 1935). Simple monohybrid segregations for the factor Ch are given in Table VIII.

TABLE VIII.

*Pure for K and p.*

*G. Type, Khaki Seed (chch) × P. Type 2, Chocolate Seed (ChCh).*
*F₁—Chocolate Seed (Chch).*

| F₂ Family No. | P. Type 2 | G. Type |
|---|---|---|
| | Chocolate seed | Khaki seed |
| D.L. 127 | 109 | 39 |
| ,, 128 | 208 | 65 |
| ,, 348 | 44 | 13 |
| ,, 535 | 222 | 73 |
| ,, 536 | 284 | 95 |
| ,, 537 | 80 | 23 |
| ,, 539 | 188 | 74 |
| ,, 542 | 177 | 69 |
| ,, 583 | 357 | 115 |
| ,, 647 | 43 | 13 |
| ,, 648 | 36 | 12 |
| ,, 649 | 33 | 15 |
| ,, 651 | 93 | 35 |
| ,, 759 | 33 | 9 |
| ,, 761 | 95 | 21 |
| ,, 856 | 24 | 7 |
| ,, 956 | 19 | 7 |
| ,, 992 | 35 | 14 |
| ,, 993 | 128 | 48 |
| ,, 995 | 203 | 75 |
| Total | 2,411 | 822 |
| Expected, 3 : 1 ratio | 2,424·75 | 808·25 |

P > 0·50

With the Ch factor being present in both the parents, simple mono-hybrid segregations for the K factor are given in Table IX.

TABLE IX.

*Pure for p and Ch.*

*G. Type, Buff Seed (kk) × P. Type 2, Chocolate Seed (KK).*

*F₁—P. Type 2, Chocolate Seed (Kk).*

| F₂ Family No. | | P. Type 2 | G. Type |
|---|---|---|---|
| | | Chocolate seed | Buff seed |
| D.L. | 119 | 81 | 25 |
| ,, | 527 | 160 | 45 |
| ,, | 553 | 180 | 54 |
| ,, | 554 | 147 | 45 |
| ,, | 555 | 146 | 49 |
| ,, | 556 | 151 | 42 |
| ,, | 558 | 177 | 51 |
| ,, | 559 | 170 | 54 |
| ,, | 560 | 128 | 47 |
| ,, | 784 | 100 | 32 |
| ,, | 808 | 64 | 18 |
| Total | | 1,504 | 462 |
| Expected, 3 : 1 ratio | | 1,474·5 | 491·5 |

P > 0·10

Dihybrid segregations of the factors K and Ch are given in Table X. The Ch factor is inoperative without the K factor and hence the ratio obtained is 9 : 3 : 4.

TABLE X.

*Pure for p.*

*G. Type, Buff Seed (kk chch) × P. Type 2, Chocolate Seed (KK ChCh).*

*F₁—P. Type 2, Chocolate Seed (Kk Chch).*

| F₂ Family No. | | P. Type 2 | G. Type | |
|---|---|---|---|---|
| | | Chocolate seed | Khaki seed | Buff seed |
| D.L. | 526 | 108 | 32 | 46 |
| ,, | 528 | 81 | 23 | 40 |
| ,, | 529 | 138 | 53 | 54 |
| ,, | 530 | 140 | 52 | 65 |
| ,, | 531 | 96 | 31 | 32 |
| ,, | 532 | 80 | 35 | 44 |
| ,, | 533 | 53 | 25 | 28 |
| Total | | 696 | 251 | 309 |
| Expected, 9 : 3 : 4 ratio | | 706·5 | 235·5 | 314 |

P > 0·50

We have thus seen that the factor Ch with K gives a P. Type 2 with Chocolate seeds. The same factor Ch operating on the factor P (Pink wings) produces P. Type 3. In this type the seeds remain Buff but the flowers are purple. The vegetative parts are green. Segregations for P. Type 3 and P. Type 1 are presented in Table XI.

TABLE XI.

*Pure for Buff Seed (kk PP).*

*P. Type 1 (chch) × P. Type 3 (ChCh). F₁—P. Type 3 (Chch).*

| F₂ Family No. | P. Type 3 | P. Type 1 |
|---|---|---|
| D.L. 115 .. | 130 | 42 |
| ,, 492 .. | 29 | 12 |
| ,, 520 .. | 185 | 57 |
| ,, 521 .. | 217 | 62 |
| ,, 730 .. | 29 | 9 |
| ,, 741 .. | 92 | 29 |
| Total .. | 682 | 211 |
| Expected, 3 : 1 ratio .. | 669·75 | 223·25 |

$P > 0.30$

Families may be pure for both the k and Ch factors and segregate for the P factor only. In such cases the segregation will be between P. Type 3 and G. Type. Such segregations are presented in Table XII.

TABLE XII.

*Pure for Buff Seed (kk ChCh).*

*G. Type (pp) × P. Type 3 (PP). F₁—P. Type 3 (Pp).*

| F₂ Family No. | P. Type 3 | G. Type |
|---|---|---|
| D.L. 494 .. | 45 | 12 |
| ,, 731 .. | 9 | 3 |
| ,, 813 .. | 9 | 2 |
| ,, 814 .. | 14 | 6 |
| ,, 815 .. | 30 | 9 |
| Total .. | 107 | 32 |
| Expected, 3 : 1 ratio .. | 104·25 | 34·75 |

$P > 0.50$

Families pure for the k factor could segregate both for the P and the Ch factors. In that case there will be a dihybrid ratio in which the two end groups will be inseparable G. Types, resulting in a 9 : 3 : 4 ratio as shown in Table XIII.

TABLE XIII.

*Pure for Buff Seed (kk).*

G. Type ($pp$ $chch$) × P. Type 3 (PP ChCh).     $F_1$—P. Type 3 ($Pp$ $Chch$).

| $F_2$ Family No. | | P. Type 3 | P. Type 1 | G. Type |
|---|---|---|---|---|
| D.L.  116 | .. | 130 | 28 | 47 |
| „     588 | .. | 74 | 27 | 34 |
| „     624 | .. | 54 | 23 | 20 |
| „     726 | .. | 55 | 21 | 19 |
| Total | .. | 313 | 99 | 120 |
| Expected, 9 : 3 : 4 ratio | .. | 299·25 | 99·75 | 133 |

P > 0·30

When the factors K, P and Ch are present together, they produce P. Type 4. In this type the seeds turn Black. The leaf axil is purple and the flowers are purple.

In this three factor play, families can be pure for P and Ch and segregate for K. Such segregations are presented in Table XIV.

TABLE XIV.

*Pure for PP ChCh.*

P. Type 3, Buff Seed ($kk$) × P. Type 4, Black Seed (KK).

$F_1$—P. Type 4, Black Seed (Kk).

| $F_2$ Family No. | | Black seed | Buff seed |
|---|---|---|---|
| | | P. Type 4 | P. Type 3 |
| D.L.  704 | .. | 7 | 2 |
| „     711 | .. | 36 | 14 |
| „     715 | .. | 26 | 7 |
| „     717 | .. | 19 | 7 |
| „     719 | .. | 18 | 6 |
| „     1097 | .. | 183 | 67 |
| „     1133 | .. | 322 | 127 |
| Total | .. | 611 | 230 |
| Expected, 3 : 1 ratio | .. | 630·75 | 210·25 |

P > 0·10

They could be pure for the factors K and Ch and segregate for the factor P.   Such segregations are given in Table XV.

TABLE XV.

*Pure for KK ChCh.*

P. *Type 2, Chocolate Seed (pp)* × P. *Type 4, Black Seed (PP).*

$F_1$—P. *Type 4, Black Seed (Pp).*

| F₂ Family No. | P. Type 4 | P. Type 2 |
|---|---|---|
| | Black seed | Chocolate seed |
| D.L.    642   .. | 36 | 12 |
| ,,      643   .. | 79 | 24 |
| ,,      903   .. | 6 | 2 |
| ,,      990   .. | 73 | 20 |
| Total   .. | 194 | 58 |
| Expected, 3 : 1 ratio   .. | 189 | 63 |

$$P > 0.30$$

Experiences in which families are pure for K and P and segregate for the Ch factor are given in Table XVI.

TABLE XVI.

*Pure for KK PP.*

P. *Type 1, Khaki Seed (chch)* × P. *Type 4, Black Seed (ChCh).*

$F_1$—P. *Type 4, Black Seed (Chch).*

| F₂ Family No. | P. Type 4 | P. Type 1 |
|---|---|---|
| | Black seed | Khaki seed |
| D.L.    644   .. | 19 | 6 |
| ,,      985   .. | 158 | 49 |
| ,,      1084  .. | 300 | 100 |
| Total   .. | 477 | 155 |
| Expected, 3 : 1 ratio   .. | 474 | 158 |

$$P > 0.70$$

In one instance dihybrid segegations for both the factors K and Ch have been obtained, the family being pure for the P factor. *Vide* Table XVII.

TABLE XVII.

*Pure for PP.*

*P. Type 1, Buff Seed (kk chch) × P. Type 4, Black Seed (KK ChCh).*
*F₁—P. Type 4, Black Seed (Kk Chch).*

| F₂ Family No. | Black seed | Khaki seed | Buff seed | |
|---|---|---|---|---|
| | P. Type 4 | P. Type 1 | P. Type 3 | P. Type 1 |
| D.L.    701    .. | 19 | 7 | 8 | 1 |
| ,,      708    .. | 8 | 2 | 2 | 1 |
| ,,      713    .. | 17 | 6 | 8 | 1 |
| Total    .. | 44 | 15 | 18 | 3 |
| Expected, 9 : 3 : 3 : 1 ratio    .. | 45 | 15 | 15 | 5 |

$$P > 0.70$$

To a P. Type 4, the addition of an intensification factor I results in the production of P. Type 5. The chief effect of the I factor is the resultant development of internodal purple. P. Type 5 is the highest manifestation of purple pigmentation in the field varieties. Deeper depths of manifestation than P. Type 5 (P. Type 6 and P. Type 7) are met with in the garden varieties only. In the following tables are presented various aspects of the presence and absence of the I factor in combination with the factors K, P and Ch.

In Table XVIII, given below, the I factor alone is segregating while the families are pure for K, P and Ch.

TABLE XVIII.

*Pure for Black Seed (KK PP ChCh).*

*P. Type 4 (ii)* × *P. Type 5 (II).* $F_1$—*P. Type 5 (Ii).*

| F$_2$ Family No. | P. Type 5 | P. Type 4 |
|---|---|---|
| D.L. 916 .. | 54 | 18 |
| ,, 924 .. | 90 | 29 |
| ,, 975 .. | 167 | 57 |
| ,, 976 .. | 180 | 60 |
| ,, 1020 .. | 43 | 12 |
| ,, 1117 .. | 141 | 41 |
| ,, 1118 .. | 244 | 83 |
| ,, 1120 .. | 182 | 60 |
| ,, 1123 .. | 180 | 64 |
| ,, 1124 .. | 222 | 85 |
| Total .. | 1,503 | 509 |
| Expected, 3 : 1 ratio .. | 1,509 | 503 |

$P > 0·70$

The I factor produces its effect only when all the three factors K, P and Ch are present. The absence of any one of these three factors results in the absence of the P. Type 5, even though the I factor may be present.

In the following three tables the I factor is present and each of the three factors K, P and Ch respectively is segregating. *Vide* Tables XIX, XX and XXI.

TABLE XIX.

*Pure for P, Ch and I.*

*P. Type 3, Buff Seed (kk)* × *P. Type 5, Black Seed (KK).*

$F_1$—*P. Type 5, Black Seed (Kk).*

| F$_2$ Family No. | P. Type 5 | P. Type 3 |
|---|---|---|
| | Black seed | Buff seed |
| D.L. 483 .. | 61 | 17 |
| ,, 767 .. | 11 | 3 |
| ,, 789 .. | 68 | 19 |
| ,, 791 .. | 54 | 20 |
| ,, 799 .. | 57 | 16 |
| ,, 802 .. | 52 | 17 |
| Total .. | 303 | 92 |
| Expected, 3 : 1 ratio .. | 296·25 | 98·75 |

$P > 0·30$

TABLE XX.

*Pure for K, Ch and I.*

*P. Type 2, Chocolate Seed (pp) × P. Type 5, Black Seed (PP).*
*F₁—P. Type 5, Black Seed (Pp).*

| F₂ Family No. | P. Type 5 | P. Type 2 |
|---|---|---|
| | Black seed | Chocolate seed |
| D.L. 801 .. | 24 | 8 |
| „ 902 .. | 26 | 9 |
| „ 904 .. | 61 | 20 |
| „ 905 .. | 78 | 28 |
| „ 952 .. | 19 | 6 |
| „ 1101 .. | 88 | 37 |
| „ 1103 .. | 116 | 44 |
| Total .. | 412 | 152 |
| Expected, 3 : 1 ratio .. | 423 | 141 |

$P > 0.20$

TABLE XXI.

*Pure for K, P and I.*

*P. Type 1, Khaki Seed (chch) × P. Type 5, Black Seed (ChCh).*
*F₁—P. Type 5, Black Seed (Chch).*

| F₂ Family No. | P. Type 5 | P. Type 1 |
|---|---|---|
| | Black seed | Khaki seed |
| D.L. 472 .. | 182 | 53 |
| „ 473 .. | 64 | 19 |
| „ 474 .. | 145 | 46 |
| „ 475 .. | 42 | 13 |
| „ 755 .. | 9 | 3 |
| „ 918 .. | 64 | 24 |
| „ 945 .. | 42 | 16 |
| „ 968 .. | 100 | 24 |
| Total .. | 648 | 198 |
| Expected, 3 : 1 ratio .. | 634·50 | 211·50 |

$P > 0.20$

In Tables XXII and XXIII the I factor segregates and along with it either P or Ch. This results in a dihybrid ratio of 9 : 3 : 4 in which the end group is represented by two inseparable groups due to the failure of the I factor to manifest itself unless with the conjoint presence of K, P and Ch.

TABLE XXII.

*Pure for K and Ch.*

P. Type 2, Chocolate Seed (*pp ii*) × P. Type 5, Black Seed (PP II).

$F_1$—P. Type 5, Black Seed (Pp Ii).

| F$_2$ Family No. | Black seed | | Chocolate seed |
|---|---|---|---|
| | P. Type 5 | P. Type 4 | P. Type 2 |
| D.L. 834 .. | 25 | 9 | 13 |
| ,, 910 .. | 20 | 8 | 11 |
| ,, 913 .. | 37 | 10 | 15 |
| ,, 981 .. | 75 | 26 | 46 |
| ,, 983 .. | 115 | 35 | 47 |
| ,, 1104 .. | 93 | 37 | 45 |
| ,, 1126 .. | 87 | 34 | 43 |
| ,, 1132 .. | 283 | 98 | 137 |
| Total .. | 735 | 257 | 357 |
| Expected, 9 : 3 : 4 ratio | 758·79 | 252·93 | 337·24 |

$P > 0·30$

TABLE XXIII.

*Pure for K and P.*

P. Type 1, Khaki Seed (*chch ii*) × P. Type 5, Black Seed (ChCh II).

$F_1$—P. Type 5, Black Seed (Chch Ii).

| F$_2$ Family No. | Black seed | | Khaki seed |
|---|---|---|---|
| | P. Type 5 | P. Type 4 | P. Type 1 |
| D.L. 915 .. | 43 | 18 | 26 |
| ,, 920 .. | 81 | 27 | 38 |
| ,, 922 .. | 38 | 9 | 19 |
| Total .. | 162 | 54 | 83 |
| Expected, 9 : 3 : 4 ratio | 168·18 | 56·06 | 74·75 |

$P > 0·50$

Dihybrid segregations in which the " 4 " group is separable, thus giving rise to the 9 : 3 : 3 : 1 ratio are presented in Tables XXIV, XXV and XXVI.

TABLE XXIV.

*Pure for Ch and I.*

G. *Type, Buff Seed (kk pp) × P. Type 5, Black Seed (KK PP).*

$F_1$—P. *Type 5, Black Seed (Kk Pp).*

| F₂ Family No. | Black seed | Chocolate seed | Buff seed | |
|---|---|---|---|---|
| | P. Type 5 | P. Type 2 | P. Type 3 | G. Type |
| D.L.    779    .. | 34 | 13 | 13 | 6 |
| „    788    .. | 65 | 21 | 17 | 6 |
| „    792    .. | 30 | 12 | 11 | 5 |
| Total    .. | 129 | 46 | 41 | 17 |
| Expected, 9 : 3 : 3 : 1 ratio    .. | 131·04 | 43·68 | 43·68 | 14·56 |

P > 0·80

TABLE XXV.

*Pure for P and I.*

P. *Type 1, Buff Seed (kk chch) × P. Type 5, Black Seed (KK ChCh).*

$F_1$—P. *Type 5, Black Seed (Kk Chch).*

| F₂ Family No. | Black seed | Khaki seed | Buff seed | |
|---|---|---|---|---|
| | P. Type 5 | P. Type 1 | P. Type 3 | P. Type 1 |
| D.L.    102    .. | 135 | 47 | 47 | 12 |
| Expected, 9 : 3 : 3 : 1 ratio    .. | 135·54 | 45·18 | 45·18 | 15·06 |

P > 0·80

TABLE XXVI.

*Pure for K and I.*

G. *Type, Khaki Seed* (*pp chch*) × P. *Type 5, Black Seed* (PP ChCh).

*F₁—P. Type 5, Black Seed* (Pp Chch).

| F₂ Family No. | Black seed | Chocolate seed | Khaki seed | |
|---|---|---|---|---|
| | P. Type 5 | P. Type 2 | P. Type 1 | G. Type |
| D.L. 670 .. | 102 | 24 | 26 | 15 |
| ,, 947 .. | 49 | 16 | 15 | 3 |
| ,, 951 .. | 13 | 5 | 7 | 2 |
| Total .. | 164 | 45 | 48 | 20 |
| Expected, 9 : 3 : 3 : 1 ratio .. | 155·84 | 51·94 | 51·94 | 17·31 |

P > 0·50

In a trihybrid segregation of K, P and Ch, two Buff seeded groups will be inseparable and the ratio 27 : 9 : 9 : 3 : 9 : 3 : 4 shown in Table XXVII will be obtained.

TABLE XXVII.

*Pure for I.*

G. *Type, Buff Seed* (*kk pp chch*) × P. *Type 5, Black Seed* (KK PP ChCh).

*F₁—P. Type 5, Black Seed* (Kk Pp Chch).

| F₂ Family No. | Black seed | Chocolate seed | Khaki seed | | Buff seed | | |
|---|---|---|---|---|---|---|---|
| | P. Type 5 | P. Type 2 | P. Type 1 | G. Type | P. Type 3 | P. Type 1 | G Type |
| D.L. 101 .. | 58 | 33 | 19 | 8 | 32 | 6 | 14 |
| ,, 274 .. | 111 | 29 | 26 | 11 | 23 | 8 | 7 |
| Total .. | 169 | 62 | 45 | 19 | 55 | 14 | 21 |
| Expected, 27 : 9 : 9 : 3 : 9 : 3 : 4 ratio.. | 162·45 | 54·15 | 54·15 | 18·05 | 54·15 | 18·05 | 24·06 |

P > 0·50

In all the three following tables segregation for the I factor occurs. In other respects they are identical with the segregations in Tables XXIV, XXV and XXVI, respectively. Since the I factor is inoperative except in the combined presence of K, P and Ch, the ratios obtained here are 27 : 9 : 12 : 12 : 4. *Vide* Tables XXVIII, XXIX and XXX.

TABLE XXVIII.

*Pure for Ch.*

*G. Type, Buff Seed (kk pp ii) × P. Type 5, Black Seed (KK PP II).*
*F₁—P. Type 5, Black Seed (Kk Pp Ii).*

| F₂ Family No. | Black seed | | Chocolate seed | Buff seed | |
|---|---|---|---|---|---|
| | P. Type 5 | P. Type 4 | P. Type 2 | P. Type 3 | G. Type |
| D.L.   1108   .. | 130 | 58 | 72 | 65 | 24 |
| „   1127   .. | 210 | 83 | 86 | 76 | 24 |
| Total   .. | 340 | 141 | 158 | 141 | 48 |
| Expected, 27 : 9 : 12 : 12 : 4 ratio   .. | 349·32 | 116·44 | 155·25 | 155·25 | 51·75 |

$P > 0.10$

TABLE XXIX.

*Pure for P.*

*P. Type 1, Buff Seed (kk chch ii) × P. Type 5, Black Seed (KK ChCh II).*
*F₁—P. Type 5, Black Seed (Kk Chch Ii).*

| F₂ Family No. | Black seed | | Khaki seed | Buff seed | |
|---|---|---|---|---|---|
| | P. Type 5 | P. Type 4 | P. Type 1 | P. Type 3 | P.Type 1 |
| D.L.   482   .. | 305 | 104 | 97 | 113 | 37 |
| Expected, 27 : 9 : 12 : 12 : 4 ratio   .. | 275·46 | 91·82 | 122·43 | 122·43 | 40·81 |

$P > 0.05$

TABLE XXX.

*Pure for K.*

G. *Type, Khaki Seed* (*pp chch ii*) × P. *Type, 5 Black Seed* (*PP ChCh II*).
$F_1$—P. *Type 5, Black Seed* (*Pp Chch Ii*).

| F₂ Family No. | Black seed | | Chocolate seed | Khaki seed | |
|---|---|---|---|---|---|
| | P. Type 5 | P. Type 4 | P. Type 2 | P. Type 1 | G. Type |
| D.L.. 378 .. | 142 | 50 | 55 | 55 | 26 |
| ,, 967 .. | 122 | 29 | 41 | 43 | 9 |
| ,, 982 .. | 67 | 30 | 27 | 32 | 13 |
| Total .. | 331 | 109 | 123 | 130 | 48 |
| Expected, 27 : 9 : 12 : 12 : 4 ratio .. | 312·60 | 104·20 | 138·94 | 138·94 | 46·31 |

P > 0·30

The ratio 81 : 27 : 36 : 36 : 12 : 36 : 12 : 16 is obtained when all the factors K, P, Ch and I segregate as shown in Table XXXI.

TABLE XXXI.

G. *Type, Buff Seed* (*kk pp chch ii*) × P. *Type 5, Black Seed* (*KK PP ChCh II*).
$F_1$—P. *Type 5, Black Seed* (*Kk Pp Chch Ii*).

| F₂ Family No. | Black seed | | Chocolate seed | Khaki seed | | Buff seed | | |
|---|---|---|---|---|---|---|---|---|
| | P. Type 5 | P. Type 4 | P. Type 2 | P. Type 1 | G. Type | P. Type 3 | P. Type 1 | G Type |
| D.L. 579 .. | 74 | 23 | 30 | 23 | 4 | 27 | 13 | 6 |
| ,, 580 .. | 68 | 37 | 29 | 40 | 7 | 32 | 11 | 13 |
| ,, 1089 .. | 68 | 29 | 32 | 20 | 16 | 28 | 5 | 17 |
| Total .. | 210 | 89 | 91 | 83 | 27 | 87 | 29 | 36 |
| Expected, 81 : 27 : 36 : 36 : 12 : 36 : 12 : 16 ratio .. | 206·28 | 68·76 | 91·68 | 91·68 | 30·56 | 91·68 | 30·56 | 40·75 |

P > 0·30

### 6. Garden Varieties.

P. Types 6 and 7 that occur in garden varieties only have been described above. Garden varieties are rather difficult to cross with field varieties. Such crosses as have set are under examination and the indications are that P. Type 6 and P. Type 7 represent the operation of two other dominant intensification factors. The data concerning these experiences will be presented in due course.

### 7. The Rangoon Variety.

In addition to the types described above, there is a variety that is imported into India from Rangoon. In this variety seeds are white, big and flattish, with no micropylar colour. The plants are Green Throughout except for specks of purple on the calyx cup. These plants do not set seed freely under Coimbatore conditions. Nevertheless, the relationship of this *lablab* type to the others is under pursuit and the data will be presented when successful crosses have been raised.

### 8. Summary.

In field varieties of *lablab* there are 7 Purple Pigmented and 1 Green type. Along with the four seed coat colours, Black, Chocolate, Khaki and Buff, there result the following sixteen genotypes :—

G. Type with Buff seed coat          ..   kk   pp   chch   ii   or
                                            kk   pp   ChCh   ii   or
                                            kk   pp   chch   II   or
                                            kk   pp   ChCh   II

G. Type with Khaki seed coat          ..   KK   pp   chch   ii   or
                                            KK   pp   chch   II

P. Type 1 with Buff seed coat          ..   kk   PP   chch   ii   or
                                            kk   PP   chch   II

P. Type 1 with Khaki seed coat          ..   KK   PP   chch   ii   or
                                            KK   PP   chch   II

P. Type 2 with Chocolate seed coat ..   KK   pp   ChCh   ii   or
                                            KK   pp   ChCh   II

P. Type 3 with Buff seed coat          ..   kk   PP   ChCh   ii   or
                                            kk   PP   ChCh   II

P. Type 4 with Black seed coat          ..   KK   PP   ChCh   ii

P. Type 5 with Black seed coat          ..   KK   PP   ChCh   II

P Type 7

P Type 6

Black

P Type 5

P Type 4

P Type 2

Chocolate

P Type 3

Buft

P Type 1

G Type

Khaki

Buft
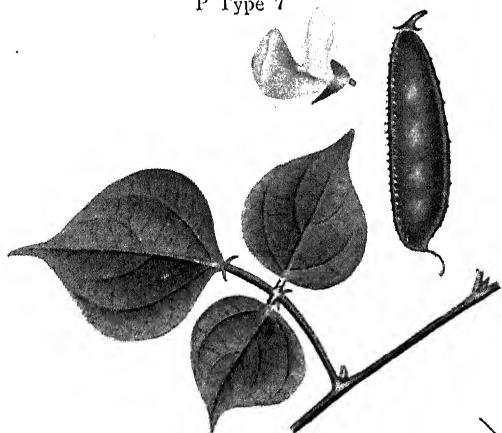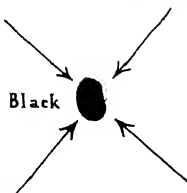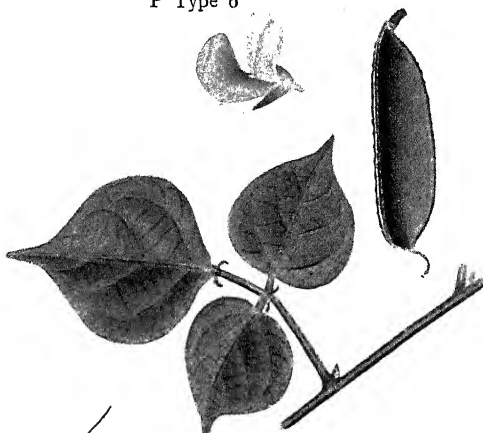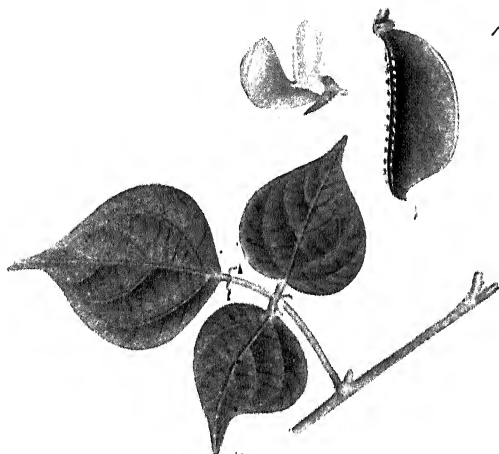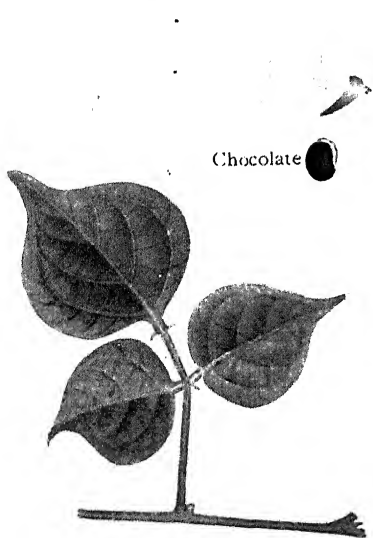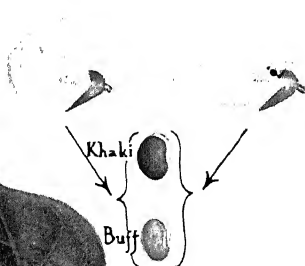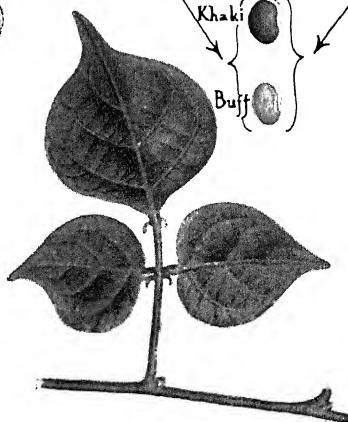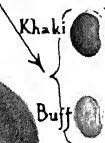
These arise by the interaction of the four factors K, P, Ch and I.   The factor K is the basic factor for the seed coat colour series Black, Chocolate and Khaki.   Alone, the K factor produces a Khaki seed coat.   With the Ch factor (which by itself is without effect) Chocolate seeds, pink ridged standard and faint purple in leaf axil and calyx are produced.   The P factor produces pink in the wing petals.   Together with the Ch factor a purple corolla is produced.   When the factors K, P and Ch are present together the leaf axils are purple, the flowers purple and the seeds Black.   An intensification factor I operating on the three factors K, P and Ch produces purple wash in the internodes and purple on the pod sutures.

Data from 160 segregating families are presented in support of the above interpretation.

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## EXPLANATION OF PLATE.

The eight plant pigment types and the related seed coat colours.

# THE PRIMITIVE CULTURE OF TRAVANCORE.*

BY L. A. KRISHNA IYER, M.A.

## I

### *Introduction.*

TRAVANCORE forms the southwestern-most part of the Deccan and bears the impact of all the racial migrations in the Deccan.. It presents a remarkable diversity of physical conditions and may be broadly divided into three distinct belts, each having its own characteristic soil, rainfall, vegetation, and cultivation. They are the Highlands, the Midlands, and the Lowlands. The Highland Division contains a long range of mountains with rich fertile lands at the foot covered mostly with rich evergreen forests. Most of the reserved forests are in this division, and the portions thrown out for cultivation are covered with rubber, tea, and cardamoms. The rainfall ranges from 100 inches in the south and more than 200 inches in the north. This region is most sparsely populated and forms the abode of the primitive tribes, the Malapantārams, the Mannans, the Muthuvans, the Paliyans, the Ūrāli, the Vishavans, the Malapulayans, the Malankuravans, the Kānikkār and the Malavētans. The Midland Division is higher in elevation than the Lowland. The soil is fertile and the rainfall varies from 55 to 140 inches per annum. Here are found the Malayarayans, the Ullātans, the Pulayans, the Parayans, and the Nayadis. In the Lowland region, where the rainfall varies from 35 inches in the south to 110 inches in the north, are found the Thantapulayans in the Sherthala Taluq. It is my purpose to describe the culture of the above primitive tribes.

It has been said that differences of geographical features are attended by differences in their customs and manners, and these again by differences in the supply of water, game, and fish, in fact, of all the necessaries and conveniences of life. The truth of the statement may be observed from the life of the Kānikkār. The average rainfall to the south of Nedumangad is about 85 inches, while it is 107 inches to the north in the vicinity of Kulathupuzha. In the south the forests are of a deciduous character, while to the north they are more evergreen and better watered. The supply of food

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B1                                                                    F

is here more stable and abundant, as they have taken to wet cultivation. They therefore enjoy greater advantages in the struggle for existence over those to the south of Nedumangad, as they have abundance of water, game, and fish, and of the fruits of the earth. These favourable conditions have reacted on their life. In the vicinity of Kulathupuzha, they have taken to wearing clothing, but to the south of Pālode, they wear very scanty clothing and their habitations are ruder in type.

### Clothing and Decoration.

Primitive man was in a state of nudity, but in the course of progressive evolution, he became subject to a sense of shame which was not in him. This sense of shame which is a by-product of modern civilization became more and more a simple manifestation of the male. Clothing seems to have originated in the decorative impulse. The first and most primitive form of clothing was to cover exposure. As typical of the level which has been classified as the fig-leaf state of society, there are several tribes in Travancore who have only recently advanced beyond that state. The Malapantārams are a tribe in the hunting stage of civilization. " The barks of trees are their clothing, and rocks, caves, and hollows of trees, their homes. Mr. Evans observed the Malavētans 'wearing dresses of leaves'. The Kānikkār call them ' Tōlvētans,' which is reminiscent of the leafy garment they wore in former times. Jacob Canter Visscher has recorded that the Ullātans wore no clothing and regarded the tiger as their uncle. The Kānikkārs were as nature made them nude with only a semblance of dress. Rev. Mateer says that " men almost go naked, having only a few inches of cloth round their loins, and a small cloth on the head. The Thantapulaya women formerly wore a *thanta* garment which covered their front and back. The garment is made of the leaves of a kind of sedge called *thanta* (Isolopes) which are cut into lengths, woven at one end and tied round the waist so that they hang below the knees and cover the front and the back. The *thanta* garment has now vanished. The Vēttuvans of North Malabar, the Juangs of Chota Nagpur, the Sakai and the Jakuns of the Malay Peninsula wore dresses of leaves. Owing to frequent contact with the people of the plains and the influence of missionaries and work in the plantations, the leafy garment has been discarded.

A German scholar propounded the theory according to which he divided clothing into two types, tropical and arctic.

The first of these is based on the waist cloth or girdle which varies between the string of beads and the cloak as two extremes. The Kānikkār of Neduvangad even now wear the scantiest of clothing. It consists of an

undercloth held in position by a string tied round the loins. Over this is suspended in front an apron 2½ feet broad a loose end of which is tucked up into the girdle tightly round the loins. They are better clad when they are in contact with the people of the plains.

Closely connected with clothing are the mutilations and deformations which are intended to serve the purpose of adornment. Among the Mala-vētans of Travancore is found the most interesting custom of chipping the upper incisor teeth in the form of short serrated cones. On being asked whether they have any tradition about the custom of tooth-filing, they replied that " it is to distinguish our caste. Our God Chathan will be angry if we neglect the custom." The operation is done by men for men. Before chipping, the outer edges of the teeth are smeared with *chunnam*. It is supposed to make chipping easier. The chipping is done with a small knife or bill-hook. The girl to be operated rests her head on thē lap of a woman who holds it firmly. A third woman takes a small knife and chips away the teeth. The custom is found among the Kādars of the Cochin State, the Malayas, and among several tribes in Africa and Australia.

The Kānikkār of Kallar also tattoo to enhance their personal beauty and it is done by a female member of the community, single-handed.

With males, tattoo assumes the circular form, while it is half-moon in the case of women. Lamp-black or charcoal powder of cocoanut shell is mixed up with breast milk of the woman. She pricks the skin on the fore-head with needles and it is painted over the pricked part every alternate day for early healing. Tattooing is found among the Kādars and Malcers of the Cochin State and the Todas of the Nilgiris.

The women have dilated ear-lobes among the Mannans, the Vēttuvans, the Malankuravans, the Malayarayans, the Ullātans, the Thantapulayans, and the Vishavans and the Malapantārams. Ear-tubes of reed or brass are worn. String beads adorn the neck of women.

*Food-quest.*

Food is the urgent and recurrent need of individuals. It dictates their activities in relation to their land at every stage of their economic develop-ment, fixes their locality for residence, and determines the extent from which maintenance may be drawn, and the duration thereon depends on the food supply. The South Indian hills have still evergreen forests yielding abundance of fruits and tubers, and streamlets, abundance of fish. There are animals for game. The Malapantārams are a small tribe in the hunting stage of civilization. They are found in high forests where the average rainfall is about 180 inches per annum. Owing to luxuriance of vegetation,

they are still within the tyranny of the jungle. They live in families of two or three in a locality. The smaller the number, the easier is the supply of food obtained. They remain for one week in a locality and then move on to another, when the food supply is exhausted. Each pack has its own jurisdiction for its wandering and food supply. They do not allow another of their tribe to encroach on their domain. If any one dares to do so, it shall be at the risk of his life. They may average one per square mile, and they live on *Arenga Wightii, Caryota urens,* and on *Curcuma Augustifolia.* The Pambu Pulayans of Anjanad live on snakes. The Kādars and Malsirs of the Cochin State and the Malavētans live on various edible roots, bamboo seeds, and others. The Kheriyas, the Birhors of Hazaribagh, and the Irulans, of the Nilgiris, wander through jungles, and subsist on yams, honey, and tubers of various kinds. Slender are the ties which fasten them to agriculture.

The Kānikkār, the Malayarayans, the Ullātans, the Ūrālis, the Mannans and the Muthuvans are nomadic agriculturists owing to diminution of edible roots and game. They have a clear conception of tribal lands. Agriculture is adopted as an adjunct to the chase. It enables them to live in one place and accumulate necessaries of life. The tribes on lower elevations have rice as their staple food, while the Malapulayans, the Mannans, the Muthuvans, and the Paliyans live on ragi and rice. All of them eat the flesh of sambhar, jungle squirrel, black monkey, and wild fowl. They also eat crabs, rats and fish.

The Ūrālis do not drink cow products. As William Crooke says, it may be that they regard it as an excrement like the Dravidian tribes of Central India. The Ullātans do not drink buffalo milk, as they fear that their gods would get annoyed and would not respond to their appeals. There is no taboo against cow's milk. Among the Kānikkār, there has been an age-long taboo against the use of milk. A Kānikkāran used to vomit and get headache, if he drank milk. The Muthuvans, the Mannans, and the Kānikkār have taken to the use of coffee, while tea has become indispensable to the Ūrālis. Living as the Ūrālis, the Muthuvans, and the Mannans are on high elevation, they are fond of arrack. In the words of Montesque, the prevalence of intoxication in different parts of the earth is proportionate to the cold and humidity of the air. It may be that a gloomy temperament and cheerless life may induce people to artificial pleasures produced by drink.

## II

### *The Production of Fire.*

The production of food is connected with the production of fire for which the savages exercise their ingenuity in a variety of ways. Like the Andamanese, the Malapantārams were ignorant of the art of making fire. Tradition

has it among the Kānikkār that Sage Narada it was who taught them how to make fire by means of hand-drill. Sticks of Unnam (*Grewia tiliæfolia*) and *Ixora Coryfolia* are used. A slot ½ inch deep is made in the centre of one stick. A man keeps it in position under his big toe, takes a round stick of hard wood 18 inches long, holds it in a vertical position keeping one end of it in the slot, and turns it quickly backwards and forwards with both his hands. A portion of the wood dust produced in the process remains in the slot and the heat generated by friction ignites it. This process was in vogue among the Malavētans and the Ullātans.

The Kānikkār also make fire by the flint and steel method. Pieces of flint and steel and some floss of *Careyota urens* are the materials required. The floss is held near the flint and the latter is struck with the steel. The friction produces sparks which ignite the floss. This process is resorted to in cold weather. The method of making fire with flint and steel is in vogue among the Muthuvans, the Mannans, the Malayarayans, and the Vishavans. It has almost died out among the Malapulayans, the Paliyans, the Malavētans, and the Ullātans. The apparatus is commonly known as chakmuk, and is so known among the ' Kādars ' of the Cochin State, and the Badagas of Nilgiris. Safety matches have now taken its place.

*Habitations.*

Natural shelters, namely caverns, overhanging rocks, holes on the ground, and hollow trunks may have been the abode of primitive man. The Malapantārams and the Kānikkār may once have occupied them. The Thantapulayans are also called Kuzhi Pulayans in memory of their having taken shelter in burrows in former times.

The Malapantārams make the simplest of dwellings. They live together in rock shelters or under breakwinds made of junglewood posts and thatched with plantain leaves which will accommodate 2 persons. The hut is circular and conical, and the floor is on a level with the ground, and has hardly room for a husband, wife and child. Boys and girls are housed for the night in separate sheds close to the parental roof. The Chenchus live in caves and the Birhors put up leaf sheds in the form of a low Kumbas or raw shelters.

The Kānikkār have a better type of dwelling. The huts are wide apart in some places. Bamboo forms the chief building material. The floor of the hut is on a level with the ground. Tree-houses are found where wild elephants roam about in parts of Klamala Reserve. A single bamboo with shoots on the sides, cut short, serves as a ladder. According to Lord Avebury, many savage tribes live in lake dwellings, and the Garos of Assam and the Kānikkār of Travancore are reckoned by him to live in dwellings 8 to 10 feet from the

ground, the object being protection from man and wild animals. A survival of this custom was found among the Kānikkār of Mothiramala, where two dwellings were seen by me. Dr. Keane does not attach much importance to pile dwellings. He does not agree that this custom was peculiar to the backward races. They are more sanitary than other huts in which they dwell. One feature of the domestic architecture of the lower culture is the institution of the bachelor-hall, where the young men of the community sleep and live. It is an important means of preserving social life. It is found to be in a conspicuous building among the Kānikkār in Mothiramala, Chembikunnu and Kottur. Unmarried girls remain in a hut vacated for them.

The Muthuvan, the Mannan, and the Paliyan huts are formed together in a group, as they are living on higher elevations. The idea of defence is the first motive, in the grouping of huts into villages. Each village has a common place of worship, a chavadi for visitors, and separate dormitories for the unmarried boys and girls. The Ūrāli huts are isolated. Each man has a tree-house which is about 50 feet above ground. They spend their nights in it for fear of elephants. Each hamlet has a common tree-house reserved for women in menses. There is a common tree-house as granary. The huts of the Malayarayans, the Ullātans, and the Malapulayans are of an improved type, as the floor is raised from the ground, and as they also have mud walling. The Vētans, the Malankuravans, and the Thantapulayans live in miserable huts. The institution of bachelor-hall is found among the Porojas of Vizagapatam agency, the Nagas, the Lusheis, the Andamanese, and others.

*Furniture and Utensils.*

The primitive tribes of Travancore live in the region of the bamboo and the reed. These materials are used for a variety of purposes. There is a family likeliness among all articles made by tropical peoples and this is accounted for by the uniformity of climate and environment. Mats made of reeds form their only furniture among the Malayarayans, the Muthuvans, and the Ūrālis. The domestic utensils consist of a few bamboo tubes whose internodes provide them with necessary bottom, a few cane baskets for keeping grain, and some brass vessels.

*Weapons and Tools.*

Primitive man ransacked his own environment and got the best out of it which his grade of culture was capable of extracting. His prime necessity was quest for food, and he was more a gatherer than a hunter. This necessitated the use of some weapon. The digging stick is still used by the Mala-pantāram, the Malavētan, the Vishavan, and others to collect wild roots and

tubers. The Kānikkār who have been using the wooden hoe for hoeing up the soil and the digging spud for digging up wild roots and tubers have taken to the use of the axe, bill-hook, and the *mammatty*.

How primitive man acquired the bow and arrow is not easily imaginable. It is just possible that it is the invention of the Negrito, as it is found in the Andamans among them, where they are in a state of hostile isolation. The bow is still used by the Kānikkār, the Ūrāli, the Muthuvan, and the Ullātan to kill animals which do damage to their crops. The bow is made of a single stave. It is made of Nara (*Polyalthia fragnans*) or bamboo. The string is made of the fibre of the adventitious roots of *Ficus* and is tied to notches at the end of the stave. The arrow is made of reed. To steady the flight of the arrow, three rows of fowl's feather are stuck into it with gum. They say that their ancestors were a stronger people and that they used to kill bigger animals. They have grown weak since they took to the use of the gun.

The Kānikkār also use the pellet-bow. They use pellets of stone which are flung with great force. The stave is made of bamboo. It is wider at the centre. It is used for killing small game and for driving away monkeys.

The Muthuvans and the Vishavans kill birds by means of the blow-gun. It is made of reed, and is 50 inches long with a diameter of $\frac{1}{4}$ inch. The dart is 5 inches long pointed at one end and winged at the other. The dart is propelled by the breath of the person and covers a distance of 50 to 75 feet. It is found among the Muthuvans of the Palni Hills and the Malays. Dr. Hutton thinks that there is no possibility at all of these blow-guns having come from the Malay Peninsula, though Mr. Foulke said that he had seen on the Madras coast blow-guns which were admittedly imported from Malay Peninsula. Dr. Hutton is of opinion that the presence of the blow-gun may possibly be credited to the Proto-Australoid. One thing is evident. It is found wherever large reeds grow.

The Vishavans use the Muppalli or three-pronged iron for spearing fish. The modern hill-tribes are aware of the use of iron.

### Exogamy.

Sir James Frazer calls Southern India the classic home of exogamy. The social organisation of the hill tribes of Travancore is built on the foundation of exogamy. Primitive people attached the greatest importance to the rules of exogamy, and the punishments inflicted for any breach thereof were very severe. It is a common rule among them never to marry a woman of their own tribal group, but always to marry a woman of a group different from their own. This means that there must be at least two sub-divisions

within a tribe. The clan may be defined as a unilateral kinship group, and traces kinship through either parent to the total exclusion of the other. The Malapantārams live in groups of two or three families on each hill. Each local group is exogamous. The Kānikkār who inhabit the interior regions of Aryanad, Kallar, and Kottur are so backward that their conditions of life have had the effect of keeping down numbers and retarding social progress. They possess the most highly developed types of exogamy. In the vicinity of Kulathupuzha, where they have been under more civilizing influences, there are only two clans. The men of each half (Mūttillom) are obliged to take their wives from the other half (Mēnillom). The effect of the division of the tribe into two exogamous classes with all the children of the same mother assigned to the same half is obviously to prevent the marriage of brothers and sisters. With a two clan system and matrilineal descent, a man's mother-in-law belongs to the clan of women who are marriageable to him, since she belongs to the same clan as her daughter, and Frazer suggested that the custom of avoidance of mother-in-law grew up in order to prevent sexual intercourse between them which the system could not bar. In less developed areas, the Kānikkār are divided into two phratries in Neyyathunkara and Villavancode taluks, each phratry having three to five clans (illoms). The partial breakdown of the exogamous classes is seen among the Ūrālis, the Ullātans, and the Malayarayans. Interesting stories are current among the Kānikkār as to the origin of the clan system. The Kānikkār of Mothiramala say that their ancestors felt an abhorence to the promiscuous life that they had in the past. With a view to evolve order out of this chaotic social condition, Illampalli Muthan and Thiruvampalli Muthan decided that there should be a dual organisation of the Kānikkār, the Annanthambi phratry and Machamby phratry. Each phratry has five clans.

Risley classified the names of exogamous clans as eponymous, territorial, and titular or totemistic. Territorial names are given among the Vishavans and the Mannans, and the names are after some village. All the tribes but the Vishavans are characterised by cross-cousin marriage. Among the Vishavans, the division of the tribe into 8 clans is said to bar the marriage of cross-cousins. They say that the prohibition of cross-cousin marriage is due to the fact that cousanguinous marriages are fraught with danger.

The system of tracing kinship through the mother is characteristic of all the hill-tribes except the Malapantārams and the Malapulayans. No man is allowed to marry a woman of his own clan. The reason for prohibition is to be found in the legal fiction that all members of the same clan are of one blood. According to Driberg, " blood cannot mate with related blood."

As a woman's children always belong to the clan different from that of her brother's children, it follows that these children who are cross-cousins can marry according to the rules of exogamy. It is significant that a child is named after a member of the mother's clan. Under the system of female descent, there was no transfer of clanship. The children belonged to the mother's clan.

### III

### *Sex and Marriage.*

Marriage, both in theory and practice, is in the melting pot. It has been built up on a system of human needs and conditions, which have hitherto been static. There are everywhere three motives which lead to marriage, mutual sympathy, the desire for progeny, and the necessity for mutual aid in the struggle for existence. Primitive marriage was dictated by the inexorable population need. Travancore is one of the ideal places for the study of primitive marriage institutions. Marriage is the joining together of a man and a woman. Before marriage, the sexes were separated by sexual taboo. At marriage, they are joined together by the same ideas worked to their logical conclusion in reciprocity of relations. Those who are mutually taboo now break the taboo. Speaking generally, marriage is the source of the family, the safeguard of public morals, the strength of the nation.

### *Cross-Cousin Marriage.*

Exogamy is found among most of the primitive tribes of Travancore. The division of a tribe into exogamous clans is a well recognised phenomenon. A man may marry the daughter of his mother's brother or his father's sister. The practice of cross-cousin marriage may have had its origin on economic grounds. It serves the purpose of keeping together related families. Briffault thinks that the idea of distance and ignorance of the tribes in other localities with whom they can enter into conjugal relations must also be another reason. In his opinion, girls are never given in marriage to young men who live in distant places. Among matriarchal and patriarchal families cross-cousin marriage keeps not only the families together, but also prevents disposal of property. In a society where inheritance runs through females, a father wishes to provide for his son, and generally marries him to his sister's daughter. Outside Travancore, it is found among the Irulans, the Kurubas, and other tribes.

### *Forms of Marriage.*

The form of marriage varied from time to time and from society to society. The earliest form of marriage is marriage by capture. A relic of this custom is found among the Muthuvans and Mannans. A peculiar

practice among the Muthuvans is that, after the marriage is settled, the bridegroom forcibly takes away the maiden from her mother's house when she goes out for water or firewood and lives with her separately for a few days in some secluded part of the forest. They then return home, unless they are, in the meanwhile, searched for and brought back by their relatives. Among the Mannans also, it sometimes happens that a woman, if she refuses to return the love of a man, is forcibly taken away by him. They then live together in the forest for ten or twelve days, and are searched for and taken to the hamlet. The offence is generally condoned, and they are allowed to live as husband and wife. Elopement is also a recognised institution among this tribe, and is resorted to, if parents object to the union of man and woman. Marriage by capture is found among the Malayalis of North Arcot and the Mullu Kurumbans of Waynad, and the Gonds of Central India.

Marriage by service is an earlier form of marriage by purchase. It is prevalent among the Paliyans and the Mannans. Among them, the bridegroom lives with his future father-in-law for six months to one year, and renders service to him before the marriage is consummated. It is found among the Esquimo, North and South American Indians, and Siberian peoples. It is a substitute for marriage by purchase, where the purchaser is too poor to pay the bride-price.

Marriage by purchase is the recognised form of marriage not only among the least civilised races, but also among the peoples who have reached the higher degree of culture. The bride-price which is generally given to the father goes to meet either wholly or partly the expenses of the marriage. It is found among the Malavetans, the Malankuravans, the Thantapulayans, and the Malapulayans. A portion of it goes to the mother and the maternal uncle and aunt among the Thantapulayans. Sometimes marriage by purchase may not be really so, for the bridal gift may be an expression of good-will or ability to keep a wife and may serve as a protection to the wife against ill-usage, and to the husband against misbehaviour on the part of the wife. This is the case among the Malavetans and Malankuravans.

Marriage by exchange of sisters is found among the Ūrālis, and the Ullātans. No man can have a wife unless he has a sister whom he can give in exchange. He cannot purchase a wife from her parent by giving the equivalent in property of some kind. The age of the girl to be given in exchange is of no consideration. Any Ūrāli who has no sister to offer in exchange has to lead a life of single blessedness. This custom prevails among the Madigas of Nilgiris, the Bhotias of Almora and some tribes in Baluchistan.

Most of the primitive tribes are monogamous and the family is regarded as the corner stone of society. Weddings are generally at dusk among most of them. The custom is due to a desire to protect the bride and bridegroom from dangers. The maternal uncle plays an important part in the settlement of marriage among the matriarchal tribes. Polygamy is in vogue among the Ūrālis, the Kānikkār, the Malayarayans, the Paliyans, and the Malapulayans. Polyandry in its fraternal form is found among the Malayarayans, the Ullātans, the Paliyans, and the Ūrālis. All the tribes prohibit pre-marital intercourse between the sexes. Pre-puberty coition is permitted among the Vishavans, the Kānikkār, and the Chīngannivētans. Early intercourse is injurious to health. The chastity of women is highly valued, and any breach of it is severely punished.

### The Family.

The family is the institution charged with the duty of racial perpetuation and includes wife, husband, and their offspring as also other relatives who are charged with the rights and duties towards parents and offspring. The family is the basis of the whole structure, economic, ethical, moral, and religious. Among the Malapantārams, the family consists of father, mother, and children. The union is founded on the enjoyment of such bodily functions as copulation, gestation, and lactation. The family bonds are loose and domestic affection is wanting between husband and wife. They quarrel in no time, and the husband deserts the wife. The difficulty of living is said to be the cause of want of attachment. Just for a measure of rice, a Malapantāram is said to have given away one of his children. Instances of desertion of children are not wanting even now. Family bonds are stronger among all the tribes who have taken to agriculture.

### Property.

Closely connected with marriage and family is property, the three kinds of which are personal, family, and tribal. Where agriculture is practised, the lands belong to the Community. This in due course leads to the evolution of private property as a result of effective occupation. According to Westermarck, the ordinary custom of savages is that the dead man's property is inherited by his own children, if kinship is reckoned through the father and by his sister's children, if kinship is through the female. The right to inherit a dead man's property was certainly co-extensive with the duty of performing his obsequies and offering sacrifices to his spirit. Among the Ūrālis, the nephew is the chief mourner. This indicates the former prevalence of matriarchate among the Ūrālis. Now the children of the dead man inherit property, because they have been previously in joint possession of it, for possession leads to ownership. It is interesting to observe that the nephew

is the chief mourner among the Thantapulayans and he observes pollution for 16 days. The wife and children do not observe any pollution. Inheritance is in the female line among them. The nephew is the chief mourner among the Muthuvans and the Vishavans, and inheritance is in the female line among them. Among the Kānikkār, the nephew washes the corpse above the waist, and below this, the son. It is therefore a mixture of matriarchy and patriarchy among them, as it is among the Malavētans, the Paliyans. Inheritance is in the male line among the Malapantārams, among whom property devolves on sons in common. Where they are under civilizing influences, it is a mixture of matriarchy and patriarchy.

## *Group Solidarity.*

It is a characteristic feature of primitive society that a member of a tribe considers that he forms part and parcel of the tribe and never regards himself as a separate unit. The Malapantārams are in the hunting stage of civilization. Their low economic condition is reflected in their simple organisation, which has little cohesion, because it must be prepared to break up when its food supplies decrease even little. The larger the amount of territory necessary for the support of a given community the looser the connnection between land and people, and the lower the type of social organisation. In Pathanapuram, where they are under more civilizing influences, they have a headman called " Mūppan".

The Kānikkār are knit together by social, religious, and political ties. The village is the unit in all matters and there is no room for the play of individualistic tendencies. Villagers work jointly in clearing jungle, burning debris, and in all magico-religious ceremonies performed for securing a bountiful harvest. The headman used to wield considerable power in the past and settle all their disputes. He is the final authority in all matters, social, religious, and agricultural.

The Muthuvans have the Mēlvāka as their supreme lord and Kiliparambu forms his headquarters. Inferior to him is the Mūthākka. On the Cardamon Hills, each village has its own headman and village affairs were regulated by a council of elders. Their supreme lord is Mēlvāka. References are made to a dignitory lower in rank. Under him comes the Thalayari who has jurisdiction over two or three villages. Then follow the Kularan and Sundarapandi who are equivalents of village chiefs.

The Malavētans, the Malankuruvans, the Pulayans, and the Thantapulayans were slaves of the soil till 1854, when they were emancipated. Even now, their condition has not undergone any material improvement. Their masters settle their disputes.

### Taboo.

Taboo forms the basis of the society among the primitive tribes of Travancore. The primitive conception of danger appears in two forms, the prediction of evil influences and the imposition of taboos. These appear with greater force at their sexual crisis, that is, at puberty, during menstrual periods, pregnancy, and after child-birth. All contacts are contagious. The avoidance of contact is the most prominent feature attached to cases of taboo.

At puberty, it is a widespread custom that neither sex may see each other. With the onset of puberty, the sexual question appears, which emphasises the separation, both natural and taboo, and at the ceremonies of initiation, boys are taken away from the mother's sphere and female associations. A common form of this custom is the institution of public buildings which combine the features of a dormitory and a club for the use of youngmen, so that they may not see nor have any association with females. Such dormitories are found among the Muthuvans and Mannans. Contact with women is dangerous, causing weakness and effeminacy.

The motive for the restrictions commonly imposed on girls at puberty is the deeply engrained dread which the primitive man entertains of menstruous blood. He fears it at all times, but especially on its first appearance. To obviate this danger, a Malapantāram girl at puberty is lodged in a seclusion-shed about 100 yards from the main hut for sixteen days. Among the Ūrālis, when a girl attains puberty, she is lodged in a remote tree-house reserved for the purpose from seven to twelve days. She bathes on the eighth day, moves on to a second tree-house in the vicinity and remains there for two days in seclusion. On the third day, she bathes and returns home, when seven jack spoonfuls of cowdung mixed with water and oil are poured over her head by her uncle and brothers in front of the hut.

According to Pliny, the touch of a menstruous woman turned wine into vinegar, blighted crops, killed seedlings, blasted gardens, brought down the fruit from the tree. The object of secluding women at menstruation is to neutralise the dangerous influences which are supposed to emanate from them at such times. A Malapantāram woman in menstruation remains in a seclusion-shed for seven days. It is about 100 yards from the hut. During the period, the husband is forbidden to ascend a hill or climb a tree for gathering honey. Woe befalls him, if he acts differently. The mode of removing contagion is purification by bath at the end of the period of pollution. The separation of the sexes during menstruation is a characteristic feature of all the hill-tribes of Travancore. Among the Ūrālis, a woman remains secluded in a remote tree-house until discharge ceases. She then bathes and goes to a

second tree-house in the vicinity. She remains there for two days and returns home after bath on the third day.    Great harm is feared for crops, if she goes before discharge.

The phenomenon of child-birth partakes of the mysterious and supernatural. The Malapantārams regard the pollution of child-birth as much more dangerous than that of menstruation, and a woman is confined to a shed about two or three hundred yards away from the hut.    Pollution lasts for sixteen days.    During this period, the husband cannot do any work.    He cannot go out for hunting or for gathering honey.    Among the Ūrālis, childbirth takes place in a tree-house remote from the habitation.    One of the reasons why the actual birth of a child and menstruation are considered dangerous is that blood is regarded as the life force, it being held that the soul or the spirit is in the blood, and a woman because of her fertility is more highly charged with this mystical force than man.    The slightest contact with feminine blood is regarded with the utmost horror.    It may be observed that the main line of development of ritual is from insulation of evil influences to the conciliation of beneficent powers.    The dangers feared are insulated during the process of the function, the expulsion of the danger is performed for the last time, and is of a purificatory character.

During the period of agricultural operations, the Ullātans lead a celibate life.    Since they live in the domain of Sāsta and other hill deities, they abstain from all sexual intercourse.    It is said that a woman in menses was touched by her husband, who then went to hoe up the soil.    He lost his eyes. It is said that the shadow of such a man falling on a crop in the field will not only blight the crop, but is detrimental to his life.    It is said that sexual cleanliness is demanded of those who have anything to do with corn.    It seems that sexual intercourse and menstruation discharges are looked upon as polluting on account of the mysterious propensities of such matter.    The defiling effects are connected with the notion that woman is an unclean being.

## IV

### Religion.

The primary needs of primitive man are to secure the increase and multiplication of the resources of food, animal and vegetable.    It has been said that the more varied the course of nature throughout the year, the more persistent probably will be man's efforts to regulate it for his benefit and the firmer will be his faith in his power to do so.    In other words, the more marked the change of seasons,    the greater will tend to be the volume of magic and the belief in its efficacy.    Where nature is bounteous and her course is uniform or varies little from year's end to year's end, man will

neither need nor desire to alter it by magic or otherwise to suit his convenience. In the vicinity of Kulathupuzha, where there is heavier rainfall and permanent paddy cultivation, the Kānikkār have given up their magico-religious ceremonies at the time of the jungle-clearing, the breaking of soil, and the sowing of seed, as they have given up their primitive methods of cultivation, and as their harvest is more assured. To the south of Pālode, the Kānikkār are nomadic agriculturists. Since their food-supply is left to the uncertainties of the weather, they make their offerings at every stage. Their magico-religious ceremonies consist of two orders of procedure, the one extended to please, attract, and conciliate, and the other to avert and exercise the harm which the gods have the power to inflict. They make offerings from start to finish in their agricultural operations to deities and spirits. Their propitiation is very exacting and leaves hardly anything for the votaries to lead a life free from want. Agriculture in the lower culture is no simple business, but is a complex of many elements, sacrifices, taboos, and dances. It is the association of these elements that for the lower culture produces the results. It sees the hand of God in the changing aspects of nature and propitiates him in all stages of agricultural operations.

The primitive tribes are animists. Their attitude to the supernatural is one of reverential fear in the presence of certain supernatural powers and beings and their propitiation or conciliation to arrest ill-will. The worship of spirits on particular crests of hills is seen among the Muthuvans, the Ullātans, the Malayarayans, the Paliyans, and others. A Malapantāram dreads jungle deities so much that, if he gets polluted on the way, he bathes before he enters the jungle. Failure brings on him the wrath of the gods who punish him with illness. The Konga Malayans of Cochin worship the two demoniacal deities named after the rocks in which they reside. The village priest is generally the headman, but in some tribes, there is a medicine-man or plāthi among the Kānikkār and the Ūrālis, who cures all ailments and practises black art. Propitiation is congregational and is intended to restore men's confidence when shaken by crisis.

*Ancestor-Worship.*

Ancestor-worship is one of the great branches of the religion of mankind. It is prevalent among most of the primitive tribes of Travancore. The Malayarayans make miniature dolmens, the whole forming a box a few inches square, and on the death of a member of the family, the spirit is supposed to pass, as the body is being buried, into a brass or similar image which is shut in the vault. A few offerings of milk, rice, and toddy, and ghee are made, a torch is lighted, the figure is placed inside the cell, and the cover-stone hastily placed on. All then leave. On the anniversary day, similar offerings

are made. The stone is lifted off and hastily closed. The spirit is supposed to be enclosed. None venture to touch the cell at any other time. Ancestor-spirits go by legion among the Kānikkār.

The Muthuvans, the Mannans, the Malayarayans, and the Kānikkār show signs of the influence of Hinduism on their religion. Among the Muthuvans, a raised *thatti* is put up in a thatched shed away from the habitations. A cane and a bundle of peacock feathers are placed over it. These are emblematic of God Subramania. The function of primitive religion is much more direct, concrete, and practical. It is not to interpret life, but to obtain those things which are reckoned needful to its existence.

*Occupation.*

It has been said that social and religious progress has spread or is spreading from the sea, inland, and not in the reverse direction. The interior is less open to foreign influences and is more tenacious of old ways. This is true of the primitive tribes of Travancore. Along highway communications, the Kānikkār are more under civilizing influences and have adopted a stabler mode of wet cultivation in the vicinity of Kulathupuzha. In less accessible areas in Neduvangad and Vilavancode, they are less open to foreign influence and more tenacious of their old ways. They are here nomadic agriculturists and their whole energy is consumed in an ever-increasing struggle for bare existence. In the uplands, cultivation is migratory. In the lowlands, it is permanent. On the hills, rice is grown on the dry system. The coincidence of the dry system with the migratory cultivation is not accidental. This method of cultivation occupies the greater part of their time and leaves hardly any time for the satisfaction of their other needs. The Vishavans, the Mannans, the Muthuvans, the Ūrālis, and the Paliyans are nomadic agriculturists. The Muthuvans have also terraced cultivation in Anjanad valley. Ward and Conner speak of numberless little glades, some adapted to rice cultivation. A mountain environment often occasions a forced development of this form of agriculture among people who otherwise linger on the outskirts of cultivation. The Malapantārams are alone in the hunting stage of civilisation. Their simple and monotonous savage economy permits of no concentration of population. The smaller the number, the easier is the supply of food assured. Professor Carl Bucher calls the first-stage as the individual search for food. Where food-supply was abundant, little effort was required to secure a livelihood. A very effective bar to progress was caused by the migratory character of the hunting community which depended on the seasonal movements of the game or scarcity. The Thantapulayans, the Karavazhi Pulayans, the Vētans, and the Malankuruvans live by

the sweat of their brows. Most of the tribes evoke the admiration of the people of the plains by the manner in which they climb trees and collect honey. They also collect minor forest produce and give it to the contractor who supplies them with rice and other articles of food. They also take part in the capture of elephants on the hills.

Dr. Hutton suggests that there are many elements which suggest the Indonesian area—seclusion at puberty, tree-houses, bark cloth (*maraviri*) which however is apparently not treated after being stripped from the tree, the scissor's snare for small game, and the use of *Acacia intsia* as soap. The matrilineal system is prevalent at any rate as a survival, and a very strong one, though inheritance in the hill-tribes is usually on the Makkathayam system. Inheritance is even now matrilineal among the Muthuvans, the Mannans, the Vishavans, the Pulayans, the Thantapulayans, while it is a mixture of matriarchy and patriarchy among others. It is interesting to observe that the hill-tribes feel that the forests were theirs and that the white man and the people of the plains encroached on their rights to such an extent that they have no place to procure their food. The advent of the European planters created a new situation. "The fate of the hill-kings" says Mr. Honiss "is rather sad. For ages past, they have boasted of being the undisputed lords of the primeval forests. The elephant and the tiger were their only foes, but with snares and traps they could hold their own against their enemies. But they could not resist the onward march of a superior race. The planter approaches them in a peaceable way offering wages for their hire ; but demanding as his right the land he has purchased. The proud men of the woods decline to herd themselves with coolies and work like common people. As soon as the planter's axe is heard, the hill-kings pack all their traps and desert their homes to establish themselves in another valley. In this way they have been driven from hill to hill and valley to valley, until some have found a safe resting place in the jungles of the lowlands of Travancore."

The fate of the hill-kings continues to be sad. They are still in a state of chronic want. They are still nomadic agriculturists driven to more uncongenial lands which yield them hardly enough to run their home for the whole year. The level of their economic life is very low. They are perpetually in debt with low countrymen.

### Importance of Anthropology.

The primitive culture of Travancore has been described so far. The practical value of this culture lies in the fact that it has a relation upon the intellectual, industrial, and social state of the cultured peoples. It explains

how our forebears passed from savagery to civilization. Every custom now in vogue among advanced society of men has its history, short or long, and can be traced back to primitive times. In the interest of posterity, the preservation of this culture is of vital importance. Anthropologists lay stress on the dangers inherent in primitives being taught by missionaries and others to despise themselves and their own religion and tribal custom. Cases of a large number of tribes who are dying out are coming into prominence. The Korwas, the Gonds, and Bhils are some instances in point. The operation of stringent forest laws is said to be one cause. The fertility of primitive tribes in Travancore is declining. Most of the tribes have but small families, the number of children ranging from one to three per family.

In attempting to improve the condition of primitive tribes, we must build on the tribal past through the agency of the tribes themselves. The attempt to aid and foster them should be the concern of the Government and should not be delegated to other agencies, though the legislature is insistent on its control of " Backward Tracts". The province of Assam affords the only illustration of a provincial administration carried on in the best interests of the primitive population, and this has been possible by the anthropological knowledge and foresight possessed by its talented administrators, Dr. Hutton and Mr. Mills. Assam serves as a model to other provincial administrations and Indian States for the treatment of backward tracts. It behoves them to consider the feasibility of having a trained anthropologist in charge of primitive areas. In that case, missionary work could be carefully watched and kept in control. The economic cycle of the primitive area could be carefully observed and economic development fostered and guided in keeping with this cycle. The tribes could be protected against unscrupulous money lenders and land-lords by special legislation. Thus the material and moral well-being of the tribes can be fostered in harmony with the times.

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A Malavĕtan digging out roots and tubers with the digging spud.
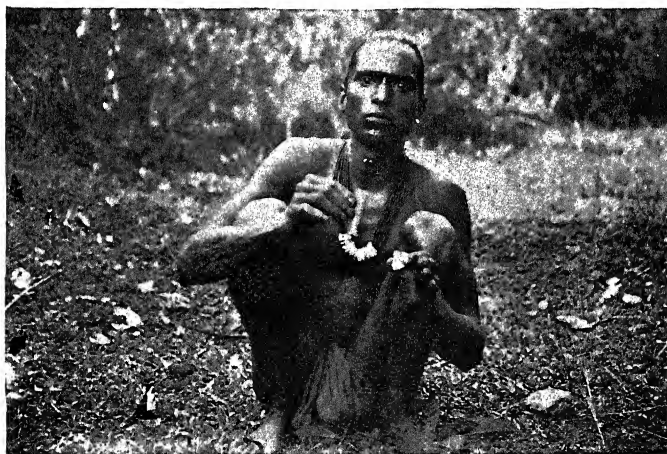


A Kānikkāran making fire by the Flint and Steel method.

A Muthuva woman making mat.



A Malayarayan group among whom polyandry prevails.



A Malapulaya shrine.

10. Ward and Conner, *Memoirs of the Survey of the Travancore and Cochin States.*
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## LIST OF ILLUSTRATIONS.

A Malavētan digging out roots and tubers with digging spud.

A Kānikkāran making fire by the Flint and Steel method.

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A Malapulaya shrine.

# MALE GENITALIA OF MALLOPHAGA INFESTING NORTH-INDIAN BIRDS.

By M. A. H. QADRI.

*(From the Zoological Laboratories, Muslim University, Aligarh, U.P., India.)*

## I. *Amblycera.*

(a) *Introduction.*—The problem of genitalia in Amblycera is extremely interesting and instructive to study. It is held generally that Amblycerans are more primitive than Ischnocerans. The presence of maxillary palpi and the horizontal and forward position of the mandibles has been held as evidence to support the above mentioned view. The study of genitalia may also help us to form an idea on the above point. Apart from that a comparative study of genitalia of various forms is undoubtedly, as Harrison and Waterston both ardently recommend, a very useful method for identifying various genera and species of Mallophaga. The task of stabilising some of the existing unwieldy genera such as *Menopon* and *Colpocephalum* will also be facilitated by the study of genitalia.

A detail and comparative study of the male genitalia of Amblycera has not so far been done. The present author does not claim to have taken any big stride towards this direction. It is simply an attempt to confirm and co-ordinate the results of various workers as well as to submit his own observations on a number of bird-infesting forms, in order to form an idea of male genitalia in Amblycera. It is unfortunate that the author could not get hold of all the important forms for his own dissections and study but he has been able to perform a number of dissections and observations on many of them. The absence of a representative collection of Mammal-infesting forms in the Museum of the Zoological Laboratories here at present has held up the studies on the genitalia of those forms. A separate description will, however, be submitted as soon as their collection is obtained.

(b) *Description of genitalia.*—The simplest form of male genitalia in Amblycera is described by Ferris in *Tetrophthalmus chilensis* Groose, in which it consists of a simple, narrow and elongated basal plate, without parameres and endomeres and is connected with an indistinct caudal expansion from which arises a very long, slender and strongly spined preputial sac. It is not easy to conclude whether the genitalia of *T. chilensis* are originally simple

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or secondarily so. The genitalia of more or less generalised features present in Amblycera have the basal plate fairly chitinised and elongated, being narrower in front. At the apex it articulates with a thinly chitinised plate on either side of which runs a slender paramere tapering towards its free end in a number of cases. The endomeres lie internal to the parameres and are in many cases shorter than parameres. Between the parameres and produced in the apical part of basal plate lies the preputial sac, which is beset with curved spines. A distinct penis can be observed in many forms, for example, in *Menacanthus masudi* Qadri (Fig. 1) and *Pseudomenopon poliocephalus* Qadri (Fig. 3).
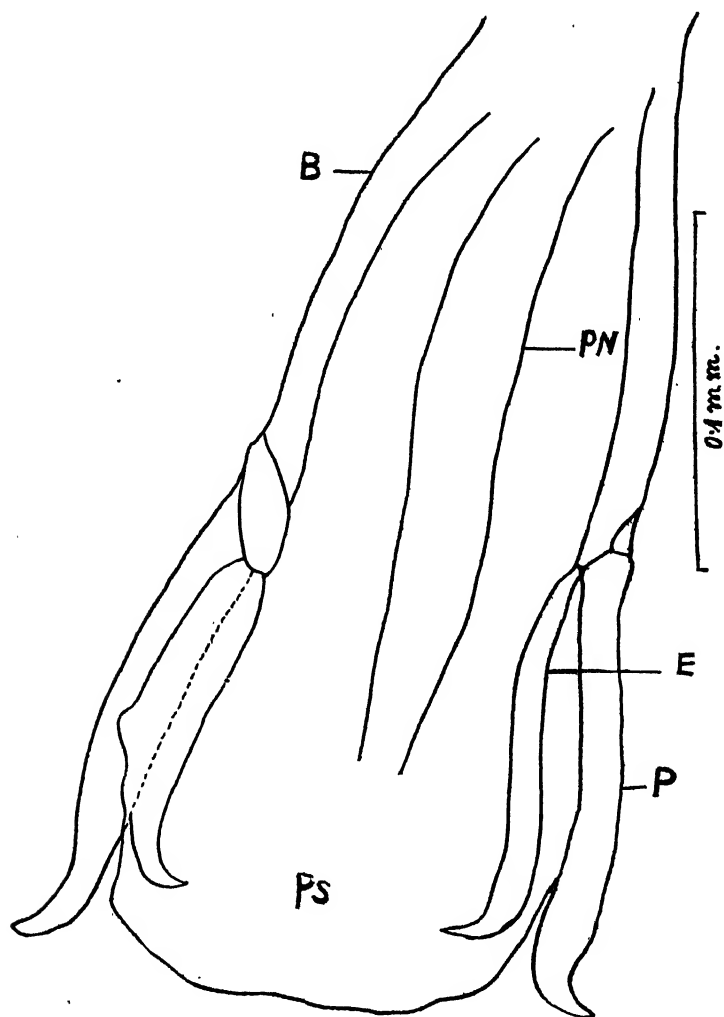


FIG. 1.
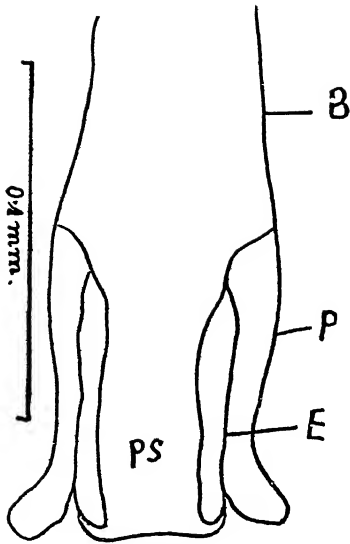
FIG. 2.
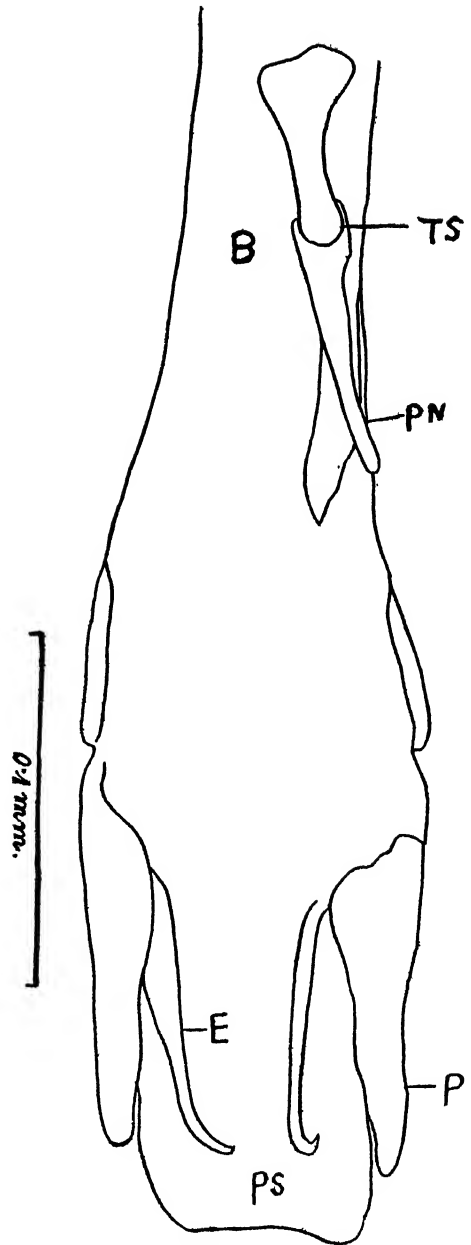


FIG. 3.

The genitalia in *Menopon* are of a more or less generalised type. The author has figured the genitalia of *M. gallinæ* Linné, to show a typical form. Fig. 2 will clearly indicate the presence of long and club-shaped parameres with distal ends, broad and directed outward. There is a pair of slender

endomeres which are pointed at their tips. The genitalia of *M. gallinæ* figured by Ferris fail to show some of the above mentioned features. It is probably owing to the overlapping of parameres and shrinking of preputial sac that the parameres and endomeres are not correctly identified by him. In *Pseudomenopon poliocephalus* there is a well-marked penis supported by a curious trumpet-shaped structure. Ferris, however, does not record the penis in *P. tridens* Nitzsch. In the former (Fig. 3) there are quite well-built endomeres and the parameres are stout and straight tapering towards their distal ends. The genitalia of a number of forms belonging to genus *Myrsidea* Waterston, studied by the author are without any great modification and are characterised by the absence of penis and endomeres. The genitalia are simple and there is no special structure in the preputial sac except a pair of ring-like structures of unknown function and homology. The male genitalia of *M. victrix* Waterston, figured by Ferris show all the essential structures therein. Among the *Trinotons* I have examined the male genitalia of *T. querquedale*, Linné, and found it to agree in all the main features with that of *T. anserinum* Fabricius, described and figured by Ferris.

The study of the genitalia of *Colpocephalum* and its allied genera show a number of important modifications in their structures. The genitalia of *C. zebra* N., have been very clearly figured by Ferris but he ignores a certain feature. The above mentioned species has not been examined by the author, but he can assert on basis of his observations on a large number of different species of *Colpocephalum* that there is a pair of parameres present which Ferris does not record, probably, missing them owing to their being thinly chitinised. In *C. semicinctum* Rudow, (Fig. 4 A) it is found that the basal plate is long and slender and is expanded at its apex. There are rod-like parameres with rounded distal ends, running straight on either side of the preputial sac. There is a pair of endomeres internal to parameres, which are faintly chitinised. The most important feature of the genitalia of *Colpocephalum* is the occurrence in the preputial sac of a complex chitinous structure near the apex of the basal plate. The structure consists of a median conical ventral plate with its broader end towards the basal plate. This plate lies between a pair of lateral chitinous plates rolling upwards to meet each other antero-dorsally and are strengthened on each side by a serrated chitinous structure. A penis-like tubular structure is posteriorly produced and is connected with the above mentioned structure.

The Colpocephalids collected from snipes and storks show an entire absence of the above mentioned structures in the preputial sacs of their male genitalia. This difference marks them out very clearly from other forms of *Colpocephalum* Nitzsch. The author has, therefore, separated them under

a new and separate genus *Pseudocolpocephalum* N. Gen.   In the male genitalia of *P. uchidai* N. sp.* (Fig. 4 B), the total absence of the chitinous structure of the preputial sac can be clearly observed.   Near the apex of the long and slender basal plate we can also observe a pair of peculiar prolongation of the preputial sac.
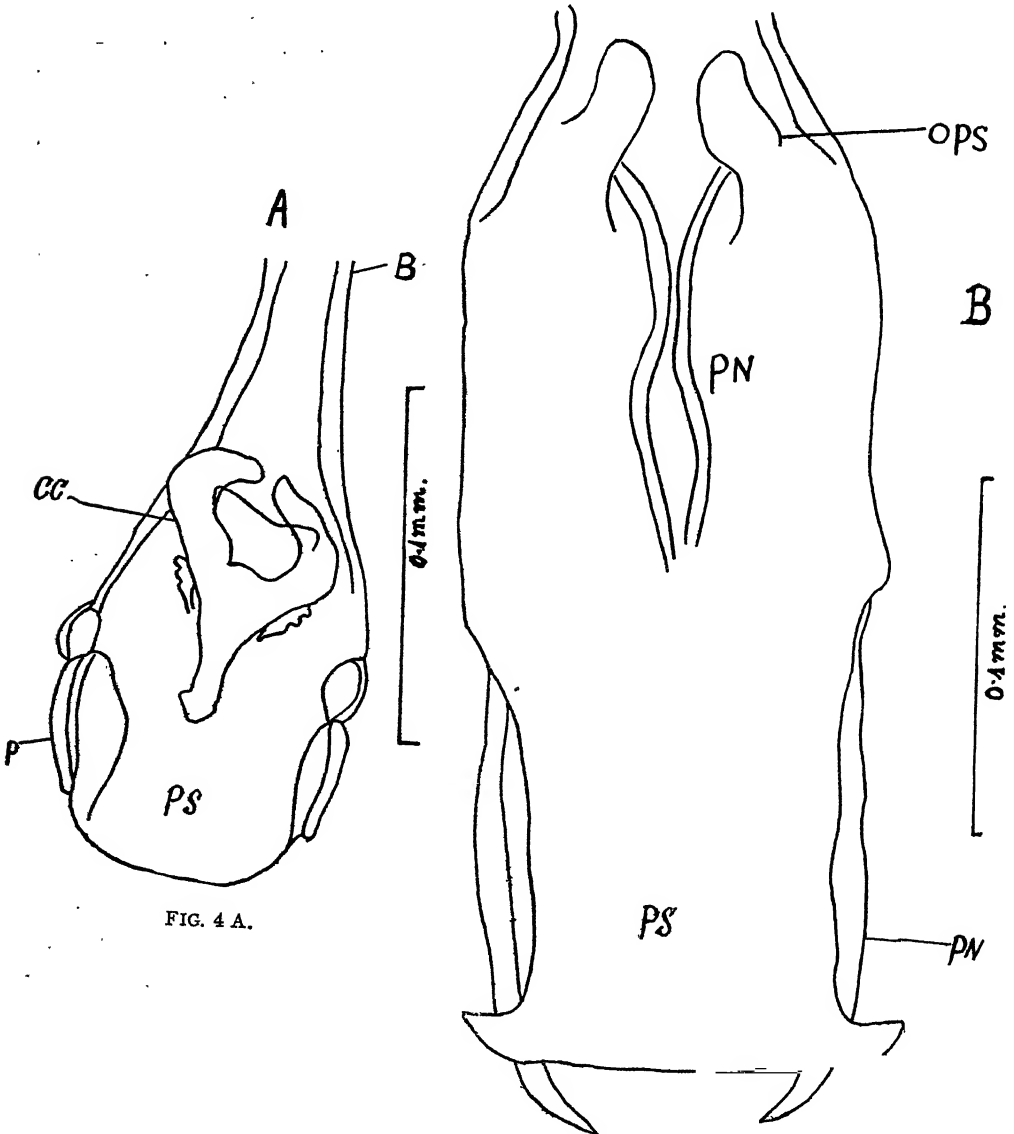


FIG. 4 A.

FIG. 4 B.

* "Some New Mallophaga from North-Indian Birds." *Zeit. f. Parasit.*, Berlin,  1936, Bd. 8, Ht. 6.

The parameres are long with their ends pointed and incurved. The endomeres are not distinctly marked. There is a tubular and chitinised penis and the sides of the preputial sac when the latter is in repose are also chitinised.

The male genital armature of *Neocolpocephalum Uchida* resembles that of *Colpocephalum* in all essential structures (Fig. 4 C), and therefore calls for no special description.
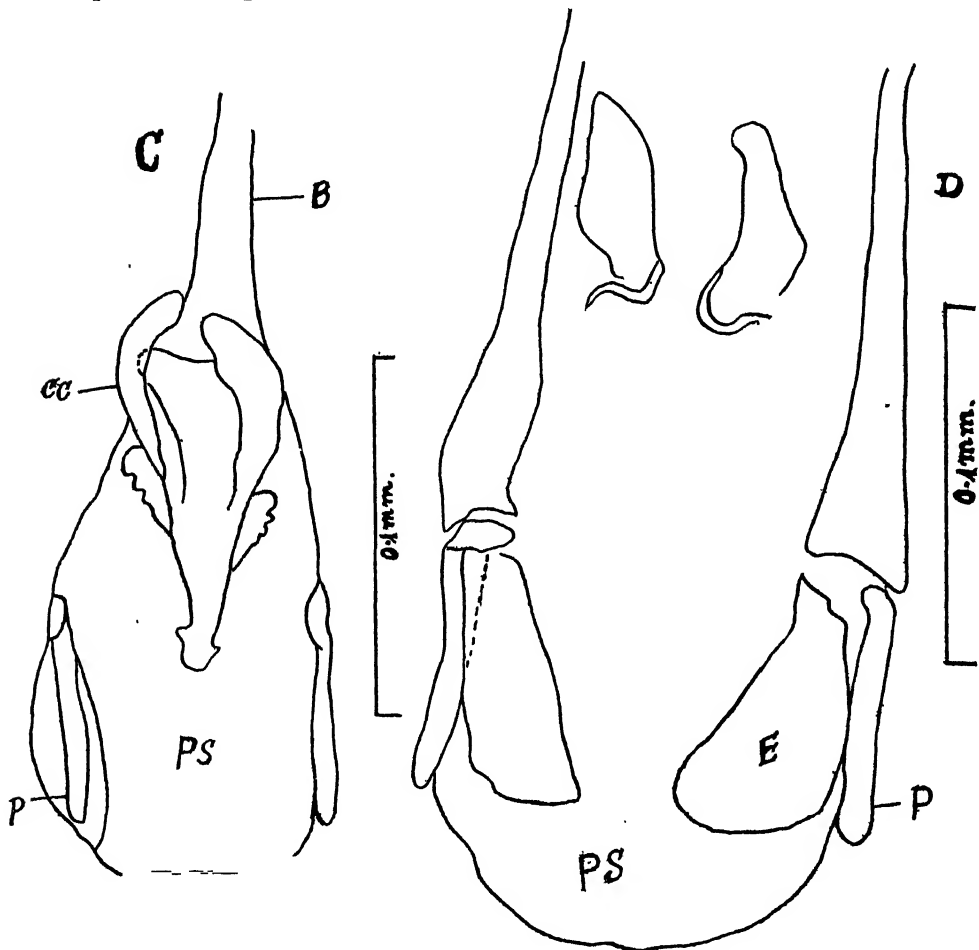


FIG. 4 C.                                    · FIG. 4 D.

The author had no access to the forms belonging to the genera *Kurodaia* Uchida, and *Heleonomus* Ferris, and therefore, cannot add more than what Uchida and Ferris have described. It is, however, evident from their description that the male genitalia of these forms are different from those of *Colpocephalum* Nitzsch. The genitalia of *Cuculiphilus fasciatus* Scopoli, figured by Uchida are different from what the author has observed in

*C. coromandus* var. *sinensis* Qadri, (Fig. 4 D). In the latter we find that the basal plate is short and parameres are straight and rod-like and endomeres are very broad, specially near their distal end. In connection with the preputial sac there is a pair of peculiar weakly chitinised structures.

The male genitalia of the *Eurem* and *Dennyus* group are more or less of generalised type as stated by Ewing, and therefore, need no separate treatment.

Among the Læmobothrionidæ, genitalia are simple and of generalised type. There is a long and slender basal plate with expanded apex. No paramere can be observed.

A pair of thinly chitinised and short endomeres run inward into the preputial sac in which no other special structures are to be found.

## II. Ischnocera.

(a) *Introduction.*—The male reproductive system and genitalia of a number of Ischnocerans have been admirably described and sketched by Cummings in his paper "Studies on the Anoplura and Mallophaga" (Pts. I and II, *P. Z. S.*, London, 1916). The author has had the opportunity of observing some of the forms examined by Cummings along with other forms of Ischnocerans infesting North-Indian birds. The present work though far from being a complete treatment of the problem in Ischnocera will, however, create an interest in the study of the genitalia of these biting-lice, which afford, as I believe, one of the most important character for the diagnosis of genera and species of Mallophaga.

(b) *Description of male genitalia :* Philopteri.—The study of the male genitalia of *Philopteri* can be conveniently and usefully conducted by assorting them into a number of sub-groups according to the various types of the hosts that the lice infest. The above system has been adopted by Cummings as well, and this makes the comparative study of male genitalia easier and more interesting than otherwise.

*Philopteri of the Crows.*—The author has examined a number of *Philopteri* from Indian crows. The male genitalia of these show a good deal of resemblance among themselves. As a type, the male genitalia of *P. rotundatus* Piaget, collected from *Corvus splendens*, have been figured (Fig. 5).

The basal plate is long and flat, with well-chitinised lateral margins. The parameres are short, incurved and wide apart. At the apex, the basal plate articulates with a median endomeral plate provided with a pair of short chitinised processes posteriorly. A very small thinly chitinised penis can be observed.
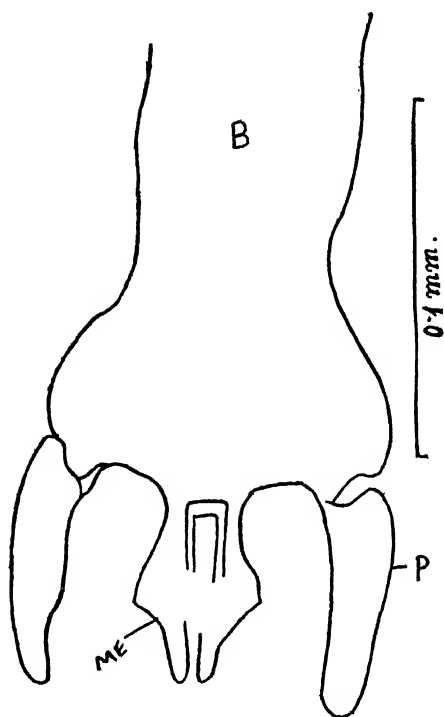
FIG. 5.

*Philopteri of the Owls.*—In the owl *Philopteri* the genitalia are compara-
tively smaller and represented as typical in *Eustrigiphilus cebelybrachys*
Nitzsch. In Fig. 6, can be seen the genitalia of *E. bramæ* Qadri, and all the
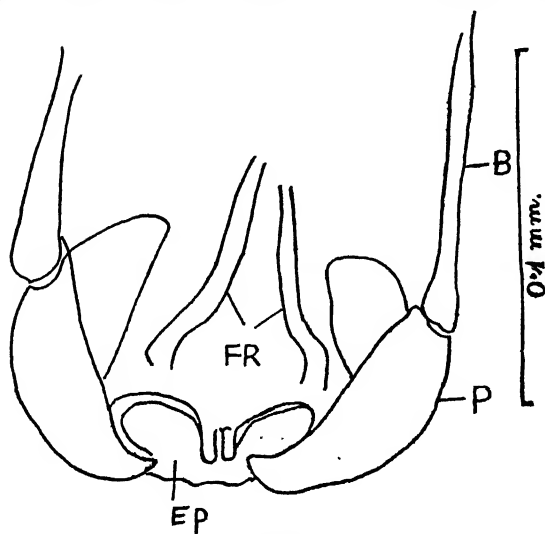


FIG. 6.

details can be compared with those of *E. cebelybrachys* Nitzsch, figured by Cummings. The most important difference between the two is that in the former the handles of the fork are separate so as to confirm its double nature.

The *Philopteri* from eagles, kites and falcons show a great resemblance with the structure which Cummings describes in *P. asturnis* Mjöberg, in the description of the genitalia of *Philopteri* of the birds of prey.

*Philopteri of Storks and Ibises.*—The genitalia of these *Philopteri* are so characteristic that they form a very important character for the differentiation of these lice from other *Philopteri*, and Cummings has, therefore, separated them into a distinct genus *Neophilopterus* Cummings. The genitalia of *N. episcopi* Kellogg, collected from *Dissoura episcopa* (Fig. 7)
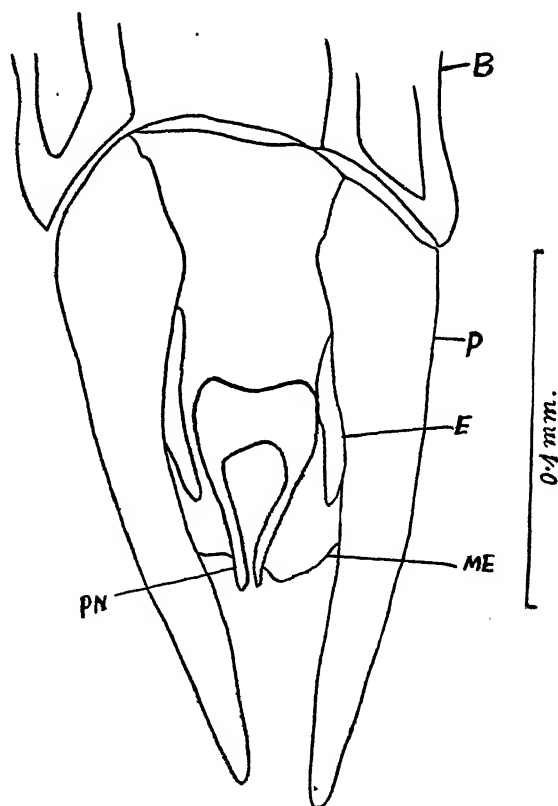


FIG. 7.

gives a further support to the view of Cummings about the diagnostic nature of male genitalia. In the genitalia of *N. episcopi* Kellogg, the basal plate is

long and broad with anterior end rounded. The lateral margins are provided with chitinous bands. The median endomeral plate is long and well defined, on the sides of which can be observed short endomeres with tapering free ends. The parameres have evenly rounded knobs. They are somewhat tapering towards their distal ends which are slightly incurved. The penis is distinct and chitinised.

While examining the *Philopteri* of Kingfisher, the author observed some male specimens of *P. alcedinis* Denny, collected from North-Indian Pied Kingfisher—*Ceryle varia*. They show a great resemblance in their male genital armature with those of forms belonging to the genus *Neophilopterus* Cummings, especially with those of *N. tricolor* N. Fig. 8 shows that the basal plate is
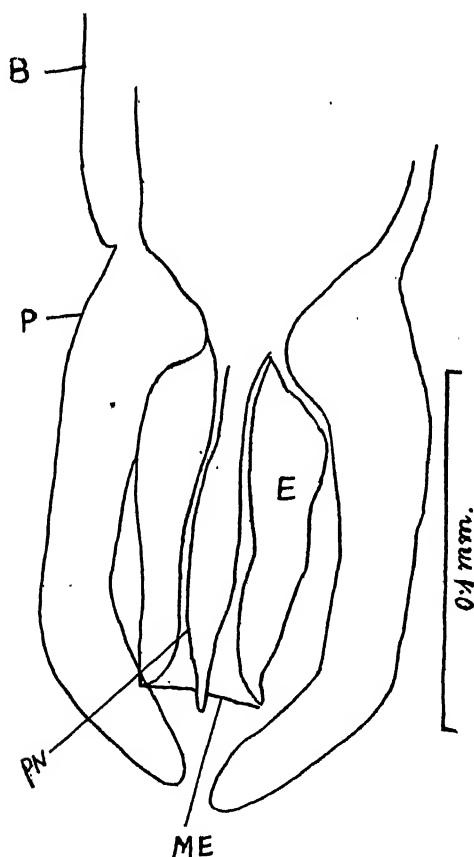


FIG. 8.

slightly longer than parameres and is provided with chitinised lateral bands. The parameres are long and incurved distally and are provided with evenly rounded proximal end. There is a median endomeral plate on the sides of

which can be observed elongated and posteriorly tapering endomeres. There is an elongated rather weakly chitinised penis between the two endomeres. The above mentioned species *P. alcedinis* Denny, cannot be included in the genus *Neophilopterus* Cummings, owing to the fact that the tergites in female are not interrupted, and there are other differences in various structures as well.

### Genitalia of Esthiopterinæ.

*Esthiopterinæ of the birds of prey.*—*E. secretarium* Giebel, (Fig. 9 A) shows a number of characteristic features of this group of lice. The basal plate is long and flat with rounded anterior end. The parameres are strong and pointed distally. The most important feature of the genitalia is the enormously long chitinised preputial sac, the sides of which are provided with
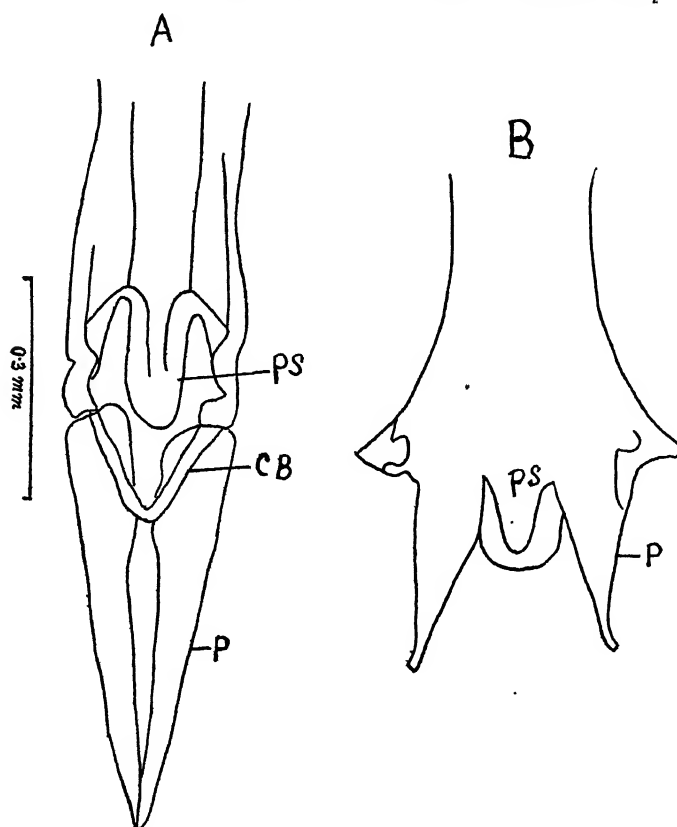


FIG. 9 A. B.

densely chitinised band. Penis is rudimentary. At the apex of the basal plate, and confined between the two parameres, there is the endomeral plate, the sides of which are provided with well-chitinised bands.

In *E. sp.* ?† collected from Indian purple coot—*Porphyrio poliocephalus* the male genitalia (Fig. 10) are extremely simple and interesting. There is
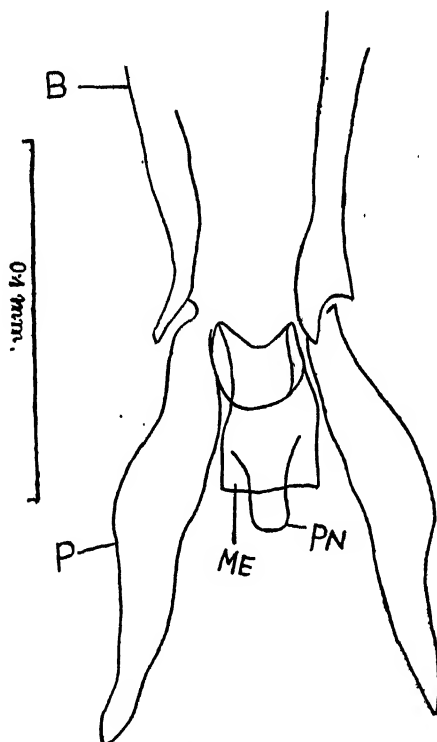


FIG. 10.

a basal plate which is short and narrow towards the apex and its sides are provided with chitinous bands. The parameres are stoutly built, tapering distally with slightly diverging ends. There is a broad median endomeral plate the sides of which are rolled upward in the anterior region. A well-formed penis can be easily observed.

The simplest type of male genitalia occur in *E. sp.* ? [From Indian Saurus crane—*Antigone antigone* (Fig. 9 B).] There is a very thinly chitinised basal plate which at its apex articulates with a pair of stout parameres with chitinised pointed ends. The preputial sac is, however, long. In *Columbicola ewingi* Qadri, (Fig. 11) there is an elongated, flat and thinly chitinised basal plate. The preputial sac is extruded and the parameres are short with incurved tapering ends. The penis is a long perfectly straight tube with an aperture at its tip, and with a forked base.

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† These lice are being identified and the results will be published shortly.

FIG. 11.

The male genitalia of lice belonging to the exceedingly large and unwieldy genus *Degeeriella* Neumann, have not been described by Cummings. After examining a few groups of these lice from birds of different families, the author has observed considerable modifications in their male genital armatures.

In *D. episcopi* Qadri, collected from *Dissoura episcopa*, the male genitalia (Fig. 12) are different from the other forms and present features typical of such lice, infesting storks. The basal plate is long and chitinised. It is constricted in the middle, and towards the apex articulates with an endomeral plate which is provided

with anterior and posterior cornu and a median posteriorly produced plate. The parameres are short but stout and bifurcated near their distal ends which are also incurved. The penis is median and well formed. In *D. olivacea* Nitzsch, (Fig. 13) collected from *Corvus splendens*, the male genital structures are typical of these forms occurring on Indian crows. The basal plate is longer than broad with chitinised lateral bands and is more chitinised anteriorly than posteriorly. It articulates with a median endomeral plate which is deeply notched posteriorly. The parameres are pointed and incurved distally and the penis is well developed. In *D. subcuspidatus* Nitzsch, collected from North-Indian Roller—*Coracilas bengalensis* (Fig. 14), the basal plate is longer than broad and thinly chitinised. The median endomeral plate is of characteristic form, with only a pair of anterior cornu articulating with the basal plate.



FIG. 12.

The parameres are sickle-shaped, stout and incurved. There is a short and tubular penis.
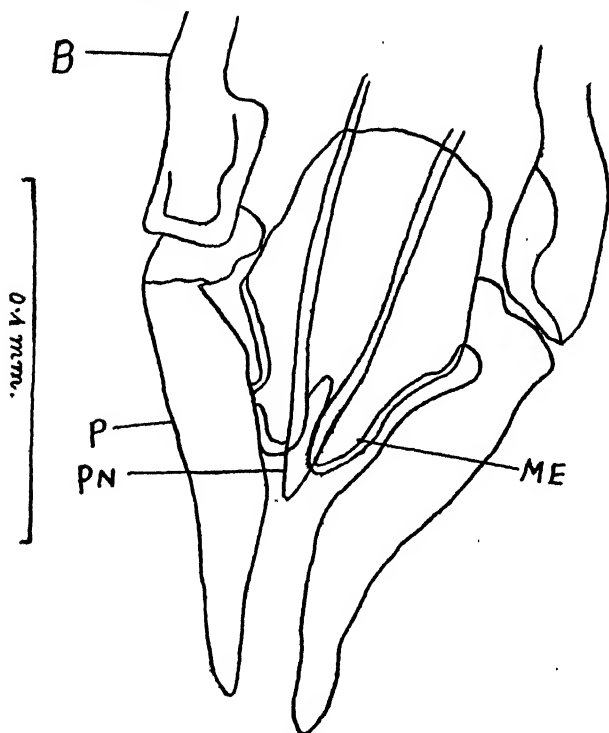


FIG. 13.
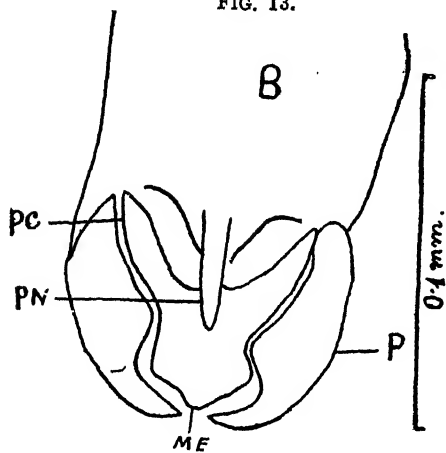
FIG. 14.
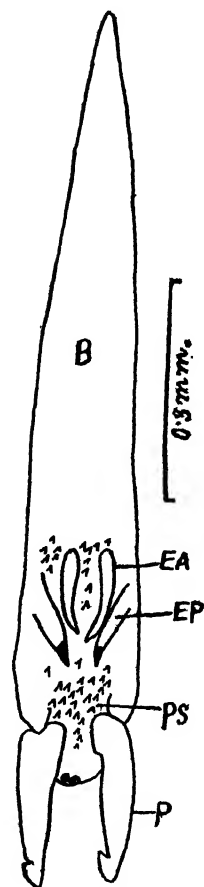
FIG. 15.

Among the forms belonging to the genus *Lipeurus* Nitzsch, from which a large number of species have been transferred to the genus *Esthiopterum* Harrison, the author had access only to *L. Caponœ* Linné (formerly known as

*L. variabilis* Nitzsch). The male genital structure (Fig. 15) is extremely characteristic and differs from many of the *Lipeuri*. The basal plate is long, chitinised and pointed anteriorly. Towards the apex it articulates with a pair of long and stout parameres tapering towards their free ends which are recurved. The preputial sac is well formed but does not extend beyond the middle of the parameres while in the resting position. It is beset with curved spines which face towards the head when the preputial sac is at rest. There are two pairs of endomeres, one anterior and inner, another posterior and external. The endomeres lie in front of the apex of the basal plate. No penis could be detected in any of the dissected specimens.

In *Goniodes dissimilis* Nitzsch, (Fig. 16) the male genital armature is very interesting and somewhat different from what Cummings has described
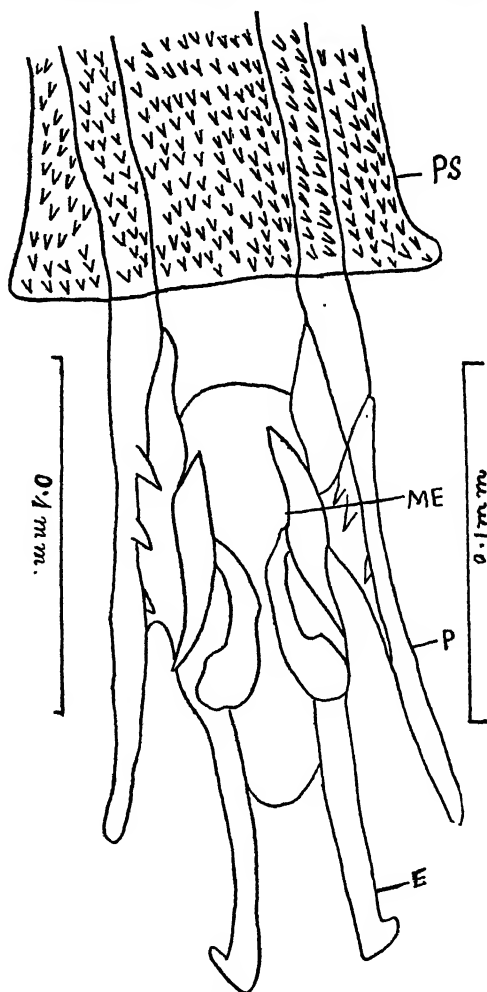


FIG. 16.

in *G. bicuspidatus* Piaget. The author had also the good luck of making observations on one specimen which was preserved *"in Copula"* and consequently various structures were clearly seen. The basal plate is long and broad. It is weakly chitinised in the middle, but is fairly chitinised on the sides which form the lateral bands. Parameres are comparatively more elongated than in *G. bicuspidatus* and are concave towards the inner side with rounded distal ends. The preputial sac is everted and is covered with spines. The posterior half of the basal plate along with other structures can be everted beyond the preputial sac. There is a median endomeral plate which is provided with a pair of posteriorly directed processes. Endomeres are also present and are long and well chitinised. They run straight and are swollen at their distal ends. When functioning, the ends of the parameres diverge to keep the female genital cavity open. The basal plate is everted, and guided by stretched endomeres, enters the genital cavity of the female. No penis was observed, and the author believes that the ejaculatory duct is everted in the female genital cavity.

### III.   Conclusion.

The above description of the male genitalia of some of the important forms belonging to Amblycera and Ischnocera, infesting Indian birds, shows in some degrees the extent of variation and modification undergone by the biting-lice in their male genital structures. It will also serve to emphasise the importance of the male genitalia in the taxonomic study of Mallophaga of both the above mentioned sub-orders. The study of homologies of the various structures is a difficult task until the development of male genital armature has been followed in important groups. Yet the author believes that for the time being they can be persued along the lines of Ewing who has studied the male genitalia of Anoplura or the sucking-lice.

Another inference which can be derived from the above study of the male genitalia of Amblycera and Ischnocera is that in the Amblycerans the male genital structures are of more generalised type and have gone less modification, whereas in Ischnocera we find that the male genitalia are much specialised along various divergent lines.

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## EXPLANATION OF FIGURES.

FIG. 1.—Male genitalia of *Menacanthus masudi*.
FIG. 2.—Male genitalia of *Menopon gallinæ*.
FIG. 3.—Male genitalia of *Pseudomenopon poliocephalus*.
FIG. 4.—Male genitalia of Colpocephalid Genera.
        A.—*Colpocephalum semicinctum*.
        B.—*Pseudocolpocephalum uchidai*.
        C.—*Neocolpocephalum gypæ*.
        D.—*Cuculiphilus coromandus* var. *siensis*.
FIG. 5.—Male genitalia of *Philopterus rotundatus*.
FIG. 6.—Male genitalia of *Eustrigiphilus bramæ*.
FIG. 7.—Male genitalia of *Neophilopterus episcopi*.
FIG. 8.—Male genitalia of *Philopterus alcedinis*.
FIG. 9.—Male genitalia of the Genus Esthiopterum:
        A.—*E. secretarium*.
        B.—*E.* sp.? (From Indian Saurus crane).
FIG. 10.—Male genitalia of *Esthiopterum* sp.? (From Indian Moorhen).
FIG. 11.—Male genitalia of *Columbicola ewingi*.
FIG. 12.—Male genitalia of *Degeeriella episcopi*.
FIG. 13.—Male genitalia of *Degeeriella olivacea*.
FIG. 14.—Male genitalia of *Degeeriella subcuspidatus*.
FIG. 15.—Male genitalia of *Lipeurus caponæ*.
FIG. 16.—Male genitalia of *Goniodes dissimilis*.

## LIST OF ABBREVIATIONS USED IN THE FIGURES.

| | | |
|---|---|---|
| B | .. .. | Basal plate. |
| CB | .. .. | Chitinous bars. |
| cc | .. .. | Compound chitinous structure. |
| E | .. .. | Endomere. |
| EP | .. .. | Endomeral plate. |
| FR | .. .. | Forked rod. |
| ME | .. .. | Median endomeral plate. |
| OPS | .. .. | Outgrowth of preputial sac. |
| P | .. .. | Paramere. |
| PC | .. .. | Posterior cornu of endomeral plate. |
| PN | .. .. | Penis. |
| PS | .. .. | Preputial sac. |
| TS | .. .. | Trumpet-shaped structure. |
| EA | .. .. | Anterior endomere. |
| PE | .. .. | Posterior endomere. |

# SOME PHASES OF THE LIFE-HISTORY OF TWO TIBETAN CARYOPHYLLACEÆ—*ARENARIA MUSCIFORMIS* WALL. AND *THYLACOSPERMUM RUPIFRAGUM* SCHRENK.

By Prakash Chandra Joshi, M.Sc.

*(From the Department of Botany, Panjab University, Lahore.)*

Recently the writer published an account of the anatomy of the vegetative parts of *Arenaria musciformis* Wall. and *Thylacospermum rupifragum* Schrenk. (Joshi, 1936). The purpose of the present paper is to describe available stages in the development of the male and female gametophytes of the two plants and the structure of the seed of the latter. The material for this investigation came from the same source as that for anatomy. It consisted in all of fairly old flowers and some fruits of *Thylacospermum*, all fixed in formalin-acetic-alcohol. The material was, as usual, embedded in paraffin and serial sections were cut 10–15 $\mu$ in thickness. The staining was mostly carried in Heidenhain's iron-alum-hæmatoxylin.

## *Arenaria musciformis* Wall.

A dissection of one of the youngest of flowers showed that the anthers contained almost ripe pollen grains and in the ovary there were ovules in a fairly advanced condition. Hooker (1875) has described the ovary of this plant to be unilocular, but examination of microtonic sections revealed it to be completely trilocular.

*The anther.*—A transverse section of an anther showed in its two halves the partition wall between the loculi either complete or broken down. The anther wall at this stage consisted of only two cell layers—the epidermis and the endothecium. Disintegrating tapetum was seen as a layer on the inside of the anther wall, showing that at maturity it does not form any kind of periplasmodium. In some cells of the tapetum one to two degenerating nuclei could be seen.

All the pollen grains in the anther are not normal, some being defective. Like those of *Stellaria media* (Joshi, 1936) the defective grains stain intense black with hæmatoxylin and are of varying size. Some are quite small and show no differentiation of the cell wall due to their early degeneration. The

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degeneration of the other pollen grains is accompanied by hypertrophy and they show a normal differentiation of the wall.

A normal pollen grain measures about 22 $\mu$ in diameter and has the usual wall consisting of a thick exine with 4 to 6 germ pores and a thin intine. The
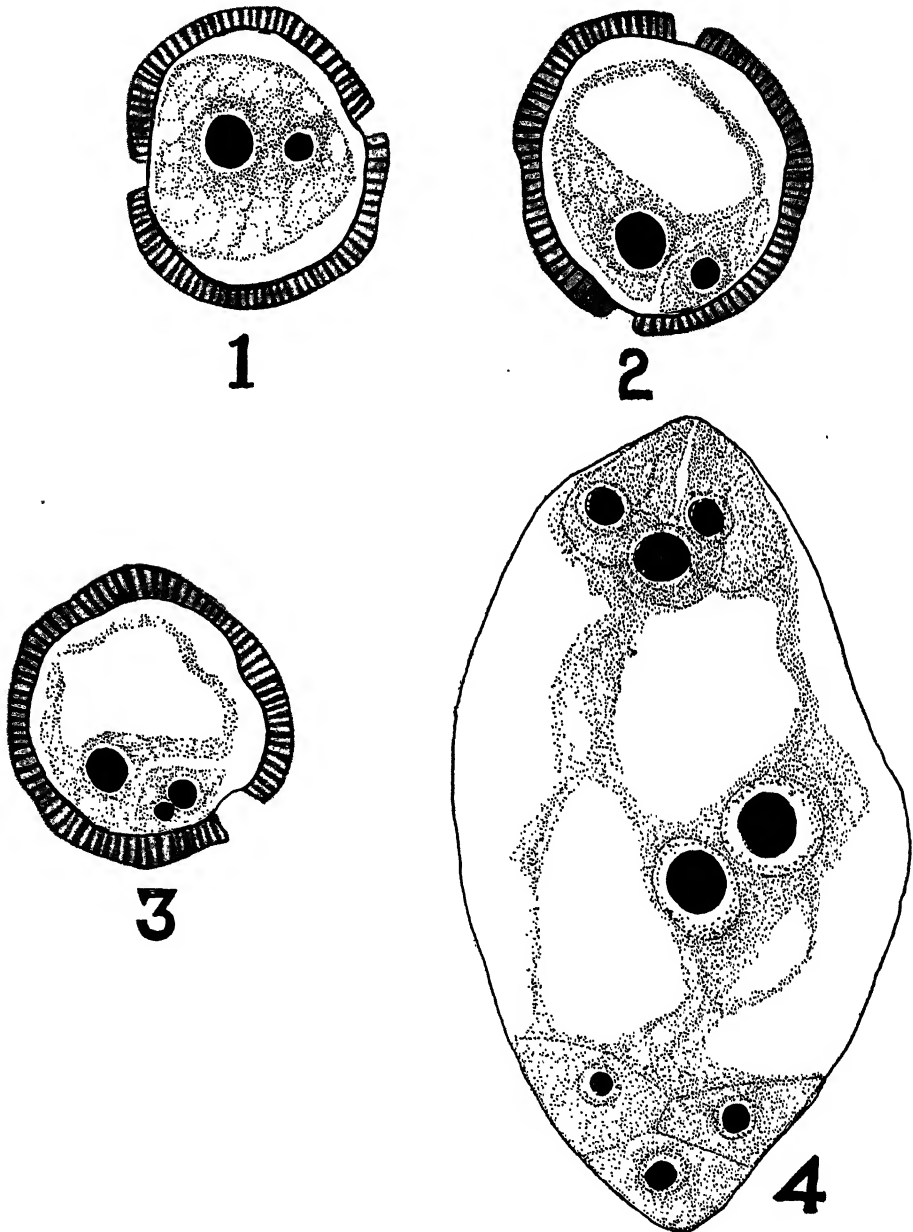
primary nucleus of the pollen grain divides into a large tube nucleus and a small generative nucleus (Fig. 1). The latter although not cut by a cell wall forms a distinct lenticular cell by the organisation of cytoplasm around it (Fig. 2). In a few pollen grains inside the anther the nucleus of the generative cell had divided (Fig. 3) and in all these cases the two resulting male nuclei were seen to be spherical in form but unequal in size.

*The ovule.*—Each ovule, as in *Stellaria media* (Joshi, 1936), has a large amount of nucellus and two integuments, the inner one forming the micropyle. Nothing could be made out of the origin of the archesporium and its further development, as the earliest stage obtained showed a two-nucleate embryo-sac. At this period no other degenerating megaspores in proximity to the embryo-sac could be seen.

A few 2-nucleate and 4-nucleate embryo-sacs and one 8-nucleate fully-formed embryo-sac have been found in the whole lot of ovules examined. On the other hand, some ovules showed no trace of any embryo-sac, its place being occupied by an empty cavity and others contained a small dark mass in its place. Moreover, most of the ovules with otherwise normal embryo-sacs showed a very small size of the sacs as compared with the corresponding stages in *Stellaria media* and a great paucity of the cytoplasmic contents in both the nucellar cells and the embryo-sacs. Added to these facts Hooker's statement that the plant has never been seen to set seeds shows that degeneration in ovules is perhaps a constant feature of *Arenaria musciformis*.

The 8-nucleate embryo-sac (Fig. 4) shows normal organisation and resembles that of *Stellaria* except for a few minor differences. The cells of the egg-apparatus are comparatively smaller, but the antipodals are quite large. Both the polar nuclei seem to move towards each other and meet in the centre of the embryo-sac. In *Stellaria*, the micropylar polar nucleus always keeps its position near the egg and only the chalazal one moves to fuse with it.

*Thylacospermum rupifragum* Schrenk.

Hooker describes the ovary of this plant as unilocular, but it is found to be almost bilocular. Two complete septa are present throughout most of its vertical length and it is only in the upper part of the ovary that the two get slightly detached from each other in the centre. In each loculus there are two campylotropous ovules with their funicles attached to the base of the placenta.

*The anther.*—All the stamens examined had almost mature anthers. The wall of the anther at this stage consists of an epidermis and an endothecium, and there are no remains even of tapetum on its inside. Very

few pollen grains in the anthers are normal. The degeneration of pollen grains in the anther seems to occur on a very large scale, perhaps exceeding 90%. The degeneration appears to take place mostly after the differentiation of the wall of the pollen grain. In some cases it is accompanied by hypertrophy (Fig. 5). The degenerated grains sometimes show other shapes than the spherical (Fig. 6), perhaps due to collapsing of their walls. Curiously enough, in some cases partially degenerated grains are seen to have produced small germ tubes while still inside the anther (Fig. 7). Such a behaviour could not be found in a single normal grain. Germination of pollen grains inside undehisced anthers has been noted in some plants. It is a marked feature of both chasmogamous and cleistogamous flowers of *Viola* (Madge, 1929 and West, 1930). Pollen tubes of considerable length have been observed inside the anthers of *Phaseolus vulgaris* by Weinstein (1926). This phenomenon occurring in the pollen of *Thylacospermum* appears to be peculiar in that it is confined only to the defective grains and is not seen in the normal ones.

A normal pollen grain of *Thylacospermum* measures about 22 $\mu$ in diameter and it has the usual thick exine and thin intine. The primary nucleus of the microspore divides into two nuclei and in some two-nucleate pollen grains there is observed little difference in the size of the two nuclei (Fig. 8). In other cases one nucleus is larger than the other. The generative nucleus forms a definite cell by accumulation of cytoplasm (Fig. 9) as in *Arenaria*. The division of the nucleus of the generative cell to form two male nuclei has not been observed in the preparations examined.

*The Ovule.*—A normal ovule of *Thylacospermum* has two integuments, the inner one forming the micropyle, and a fairly massive nucellus, just as in other Caryophyllaceæ. The youngest stage of ovule obtained showed a 2-nucleate embryo-sac and at this period of development there is no indication of the presence of any other megaspore.

The fully-formed 8-nucleate embryo-sac of *Thylacospermum* is almost of the normal type (Fig. 10). In shape it is broad in the middle and tapers towards the two ends. The structure of the egg-apparatus differs from that of *Stellaria* and *Arenaria* in the relative size of the egg-cell and the synergids, and in the form of the latter. The synergids are somewhat larger than the egg cell. According to Schnarf (1929) such a condition has been found only in rare cases. Each synergid is somewhat pyriform and has a well developed vacuole in its lower part and a big nucleus just above this embedded in a fairly large amount of cytoplasm. Laterally each synergid develops a prominent hook. Such hooked synergids have been reported in many other isolated plants of the different families, but so far in the Caryophyllaceæ their presence has been recorded only in *Spergula arvensis* (Rocén, 1927).

The egg has a large vacuole in its upper region and in its lower part lies the nucleus. The three antipodals are small. The two polar nuclei are nearly as large as the nuclei of the synergids or egg.

The degeneration of the embryo-sac and the nucellus in the ovules seems to be of quite common occurrence in this plant. Ovules from most of the flowers and the fruits cut showed either partially or completely collapsed nucellus. The former were found containing either degenerating embryo-sacs or empty spaces in their place. No stages of fertilisation or embryo formation could be obtained, except that one fruit was found to contain almost ripe seeds. The reason for the degeneration of the ovules in an advanced stage of development appears to be lack of fertilisation, which is related to the large amount of degenerations in the pollen grains, and, evidently, the lack of viable pollen.

*Abnormalities of ovules and embryo-sacs.*[1]—One flower was observed in which the integuments and the basal parts of the ovules had grown exceptionally large (Fig. 11), and as such the ovules filled the entire cavity of the ovary. The massive integuments of the ovules were of an uneven thickness and the inner one did not form any definite micropyle as in the normal case. Mostly the top of the nucellus was left uncovered and it rested directly on the wall of the ovary. The embryo-sacs found in these ovules in every case had degenerated.

One highly complex abnormality was met with in another flower with six ovules inside the ovary instead of the usual four. All the ovules were of a very unusual type. Each of them was comparatively large and very much lobed. It did not show any campylotropous curvature. A very large vascular strand from the placenta entered the base. Each such ovule consisted of almost similar nucellar cells and did not possess any definite integument. Fig. 12 gives a semi-diagrammatic representation of this condition as seen in a longitudinal section of the ovary. In each ovule one or two uppermost lobes are larger and each contains one or in some cases two embryo-sacs. On the other hand, the lobes in the lower part of the ovule are conparatively smaller and sterile. These sterile lobes cannot be interpreted as integuments as they do not form a continuous jacket round the whole structure and, moreover, their number is variable on the different sides of the ovule. The number of embryo-sacs per ovule varied from one to three and the total number of embryo-sacs present in all the six ovules came to eleven. The naked condition of the ovules inside the ovary and, in addition, the presence of more than one embryo-sac in most of them may be compared to that of

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[1] Sometime back a short note on this appeared in *Curr. Sci.*, 1935, **3**, 560–561.

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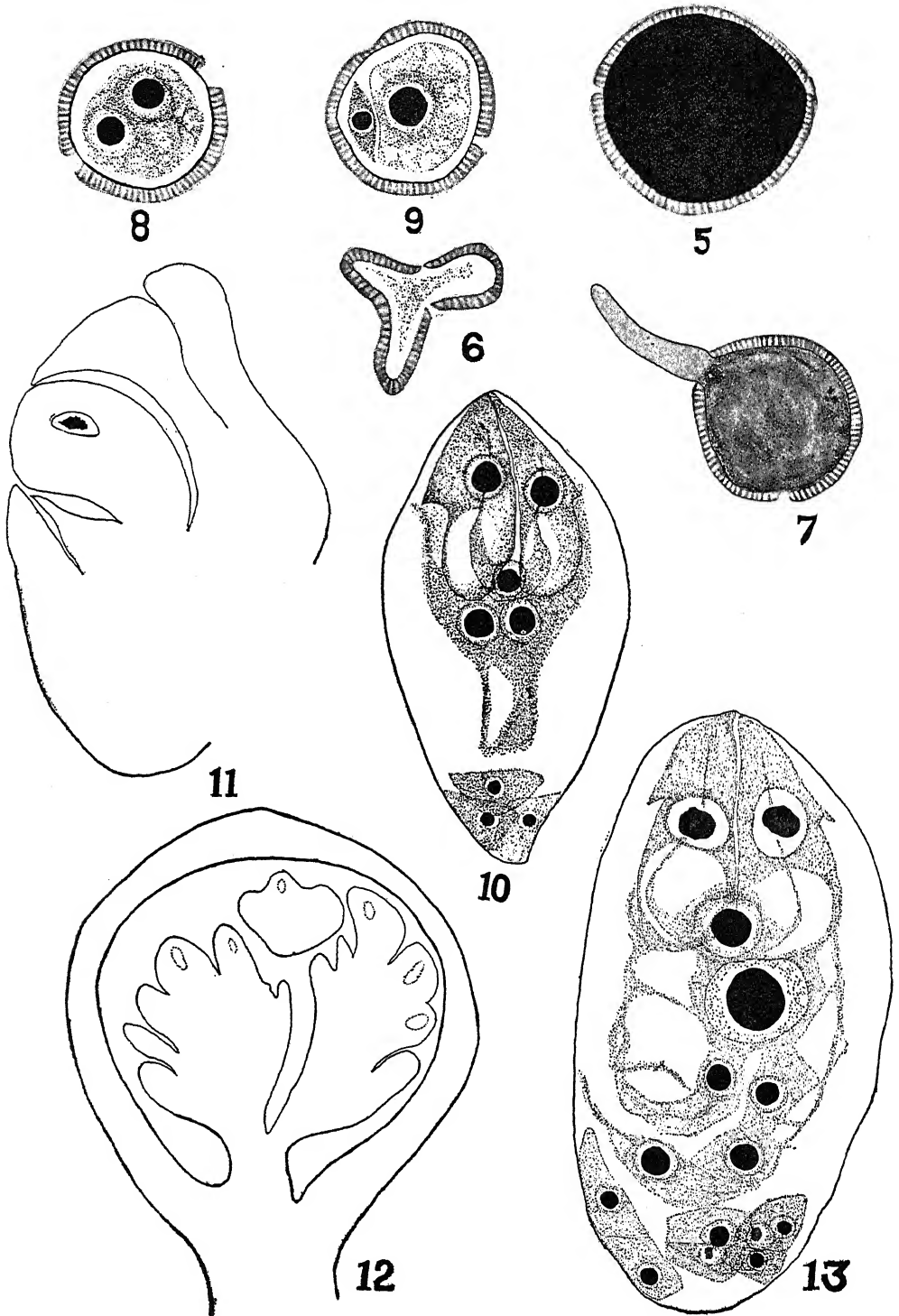
the " mamelon " of the Loranthaceæ.  Out of the eleven embryo-sacs one was found to be 4-nucleate and appeared normal.  One 8-nucleate embryo-sac was normal being similar to a mature embryo-sac of a normal ovule. Three embryo-sacs were 18-, 16-, and 4-nucleate and were of abnormal type, but the exact position of nuclei in these could not be made out.  Rest of the six embryo-sacs were also abnormal and they differed widely both from the normal embryo-sac and from one another in their size, shape and the number and organisation of the nuclei which they contained.  A detailed account of each of these embryo-sacs is given below.

On the papillæ of the stigma of the flower under consideration were seen two empty pollen grains, but no pollen tube or its remains inside the ovules or in the stylar tissue could be made out. Moreover, as the orientation of the ovules is so peculiar, it is almost certain that no fertilisation could have taken place in any of the embryo-sacs.

The first of the six embryo-sacs to be described is represented in Fig. 13.  It is a comparatively large structure with fifteen nuclei, some of which form definite cells and the others are simply seen as free nuclei.  Although the ovule shows no micropyle, yet the micropylar end of the embryo-sac is easily recognised as being opposite to the chalazal end, and the presence of an egg-apparatus in this region can be made out.  The egg-apparatus is exceptionally well developed, otherwise it is quite normal.  At the chalazal end there are seven small cells and there can be no question as to their being antipodals.  More than three antipodals have been found in several plants of the various families of the flowering plants with different affinities like Ranunculaceæ, Papaveraceæ, Thymelæaceæ, Umbelliferæ, Compositæ, etc. (Schnarf, 1929).  According to Schnarf an increase in the number of the antipodals is only a special case of the enlargement of the original three antipodals. Inbetween the egg-apparatus and the antipodals there are five free nuclei ; one of them is very large and the other four are smaller.  From the different size of these nuclei and their relative position it appears that the original endosperm nucleus has fragmented prior to degeneration.  A more pronounced similar condition is seen in the embryo-sac described next, where there are found as many as fourteen free nuclei of widely different size.

Fig. 14 shows another very large and elongated embryo-sac.  It is comparatively broad at the chalazal end and narrow at the micropylar one. Related with the latter condition, the egg-apparatus is seen to be displaced to one side of the embryo-sac.  The egg-apparatus otherwise too is very peculiar in the form of its synergids.  These are not at all pyriform but somewhat stumpy and the hooks are not differentiated properly.  The antipodals are four in number, situated in the basal part of the embryo-sac.  Three of

them form a vertical group and the fourth one lies all alone on one side. In the rest of the embryo-sac there are fourteen free nuclei of varying size. The nucleus near the egg-apparatus is quite big, but the rest are small.

The embryo-sac seen in Fig. 15 is peculiar in the structure of the three cells of its egg-apparatus, otherwise the number of the cells and the free nuclei in the whole embryo-sac is the same as in a normal one. There are three normal antipodals at the base and two polar nuclei in the middle. The egg which lies on the left hand side of the figure is relatively small and flask-shaped. The two synergids are of a very unusual outline and one of these is nearly twice the size of the other.

Fig. 16 shows one more interesting embryo-sac. Its form is peculiar in being almost equally broad at the micropylar end and the middle but very narrow at the chalazal extremity. In the egg-apparatus, the two synergids, although not of a normal shape, are easily recognised by the position of their vacuoles and the nuclei. A small hook is also visible in one of them, but instead of a normal oosphere there is seen one small cell devoid of any vacuole lying under the two synergids. Below the egg-apparatus there are the usual two polar nuclei at some distance from each other. The three antipodals are arranged in a superposed manner and occupy the narrow chalazal extremity of the embryo-sac.

The embryo-sac represented in Fig. 17 is the most striking of all the embryo-sacs described so far. It shows no polarity, being very large and almost spherical in outline. It contains the usual number of two free nuclei and six cells but arranged in a very peculiar manner. The cells are of different size and shape so that a proper interpretation of them is difficult. The two equally large nuclei lower down embedded in a reticulum of cytoplasm can be interpreted as the two polar nuclei. Taking the presence or absence of vacuoles in the cells and their relative position as the basis of interpretation, one can make a guess as to the morphological nature of the different cells. The three large cells with their nuclei almost seen in a line above the polar nucleus on the right-hand side in the figure may be considered as forming the egg-apparatus. Two of these have got vacuoles in their inner parts and the nuclei lie above the vacuoles ; these may be interpreted as the synergids. The third cell lying over the lower synergid has its nucleus at the base of the cell embedded in the cytoplasm and above it a large vacuole can be made out. It is, therefore, to be regarded as the egg-cell. The rest of the three cells of the embryo-sac in its upper portion, although of different size, are somewhat triangular in outline and lack any definite vacuoles ; these may be looked upon as the three antipodals.
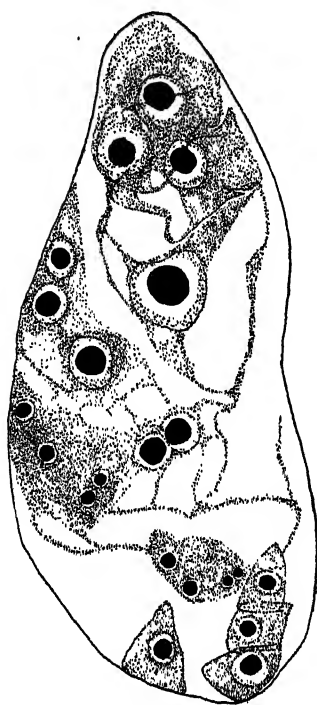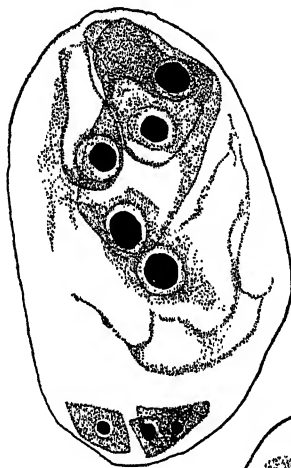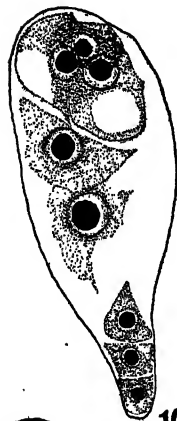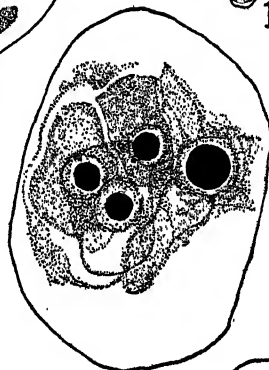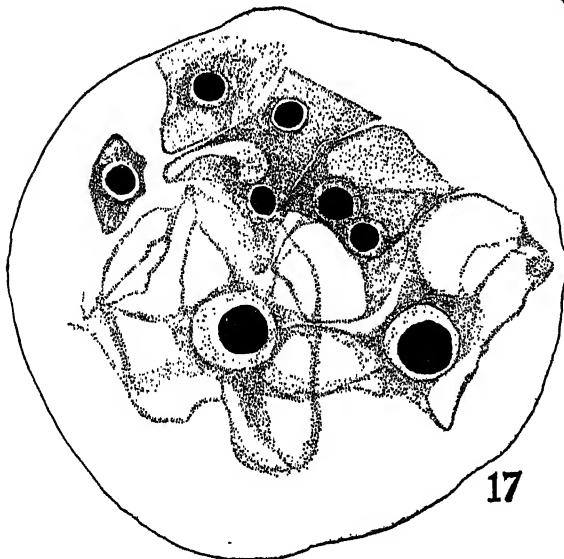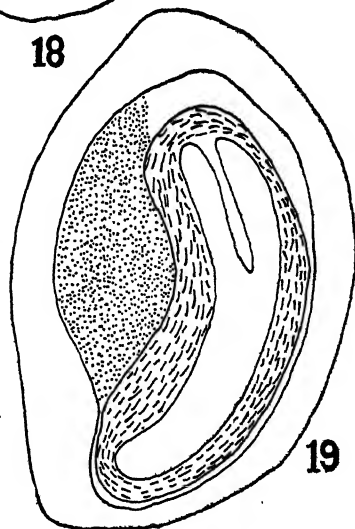
The embryo-sac drawn in Fig. 18 is small and somewhat spheroidal in shape. It contains only four nuclei; one in the form of a free nucleus and the other three forming cells, all situated near the middle of the embryo-sac. A definite morphological interpretation of these components of the embryo-sac is not possible. It appears, however, that the free nucleus is one polar nucleus. The three cells which are almost equally large, one of which is provided with a vacuole, look more like the cells of an egg-apparatus than antipodals. It may be said that the three antipodals and one polar nucleus are missing in this case. Such a condition is characteristic of onagrads, but in them a normal egg-apparatus is differentiated at the micropylar end.

*The seed.*—The structure of the seed of *Thylacospermum* is, in all essential aspects, similar to that of all other investigated species of the Caryophyllaceæ except for its endosperm. Within the testa, the embryo, lying curved on one side of the perisperm, is embedded in a complete sheath of endosperm, two to four cells thick, which fills the entire embryo-sac region (Fig. 19). The cells of the endosperm at this stage are somewhat loosely packed and almost empty, while the cells of the perisperm are full of food reserves. It is only in the family Thelygonaceæ of the order Centrospermales to which the Caryophyllaceæ belongs that in the seed the presence of cellular endosperm throughout the embryo-sac cavity has been reported, but here at the same time, the food storage tissue is endosperm and not perisperm (Woodcock, 1929), unlike the rest of the Centrospermales. In all other families of the order the early endosperm formation is free nuclear. Cell formation takes place later on to variable extension of the embryo-sac; in several instances it occupies the whole or a large part of it and in others only the micropylar end. Finally, in all cases, the endosperm found in the seed is in the form of only a cap of cells over the radicle or a single layer of distorted cells all round the embryo as is the case in the Portulacaceæ and Basellaceæ (Rocén, 1927; Schnarf, 1931; Bhargava, 1936).

*Discussion.*

The previous descriptions show that a marked feature of the life-histories of *Arenaria* and *Thylacospermum* is the large amount of degeneration in both the pollen grains and the embryo-sacs—a feature which is very insignificant in the case of *Stellaria media,* another member of the family Caryophyllaceæ worked out by the writer. In *Arenaria,* as the writer is aware, so far no seeds have been recorded by any observer, but in the absence of any other known method of propagation it is probable that these are formed rarely. The degenerations in the pollen grains and ovules in a plant have been interpreted by many workers as a sign of hybridization (Jeffrey, 1914), but it is

not possible to say whether the two plants under consideration here are products of hybridization or not. It might, however, be mentioned that Johansen (1931) has found in his studies on the morphology of the Onagraceæ, in species of *Anogra*, which are mostly restricted to deserts or at least very arid regions, a greatly decreased ability to produce viable seeds. He believes it to be a direct effect of the environment. It is possible that the degenerations in *Arenaria* and *Thylacospermum* may also be due to similar unfavourable conditions in which these plants grow.

*Summary.*

*Arenaria musciformis.*—A lenticular generative cell is organised in the 2-nucleate pollen grain. The ripe pollen grain in the anther is either 2-nucleate or 3-nucleate and the two male nuclei are spherical in form but unequal in size. A fully-formed embryo-sac is, as usual, 8-nucleate and of the normal organisation.

*Thylacospermum rupifragum.*—A definite generative cell is formed in the 2-nucleate pollen grain. The ripe pollen grain in the anther is invariably found to be only 2-nucleate. A fully formed embryo-sac differs from the normal one of *Arenaria* mainly in the structure of its egg-apparatus—the synergids possess lateral hooks and exceed the egg in the size of the cell. In the seed, the embryo, lying curved on one side of the perisperm, is embedded in a complete sheath of endosperm, two to four cells thick.

A marked feature of the life-histories of *Arenaria* and *Thylacospermum* is the large amount of degeneration in both the pollen grains and the embryo-sacs.

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## EXPLANATION OF FIGURES.

FIGS.   1–4.—*Arenaria musciformis* Wall.  $\times$ 1800.

FIG.   1.—2-nucleate pollen grain; the generative nucleus does not form a separate cell.

FIG.   2.—2-nucleate pollen grain with a small lenticular generative cell.

FIG.   3.—3-nucleate pollen grain; the two nuclei formed by the division of the generative nucleus are unequal in size.

FIG.   4.—A fully-formed 8-nucleate embryo-sac.

FIGS.   5–19.—*Thylacospermum rupifragum* Schrenk.

FIG.   5.—A large degenerated pollen grain.  $\times$ 1350.

FIG.   6.—A distorted and almost empty pollen grain.  $\times$ 1350.

FIG.   7.—A degenerated pollen grain with a small germ tube.  $\times$ 1350.

FIG.   8.—A 2-nucleate pollen grain; the two nuclei are almost of equal size. $\times$1350.

FIG.   9.—A 2-nucleate pollen grain; the generative nucleus is smaller than the tube nucleus and it forms a separate lenticular cell.  $\times$ 1350.

FIG.   10.—A normal fully-formed 8-nucleate embryo-sac.   $\times$1350.

FIGS.   11–18.—Various abnormalities of ovules and embryo-sacs (figures of the embryo-sacs have been reconstructed from two or more sections of the series). For full explanation see the main text.  FIG. 11 $\times$135; FIG. 12 $\times$72: FIGS. 13-18 $\times$1350.

FIG.   19.—An outline sketch of a section of the seed, showing the embryo lying inside a complete sheath of cellular endosperm; endosperm is represented by small tangential lines and perisperm by dots.  $\times$ 96.

# A CASE OF POLYMELY IN THE INDIAN BULL-FROG, *RANA TIGRINA* DAUD.

By Beni Charan Mahendra.

*(From the Department of Zoology, St. John's College, Agra.)*

## 1. *Introduction.*

ALTHOUGH many cases of the presence of supernumerary limbs in Salientia have been recorded from time to time, the majority being of " those in which an extra hind limb or pair of hind limbs is present " (O'Donoghue, 1910), no case, as far as I am aware, has so far been described of polymely in the common Indian bull-frog, *Rana tigrina* Daud. The extreme rarity of such an abnormality in this species is beyond doubt. For the last sixteen years, and perhaps more, we have been using over 600 individuals of this species *per annum* in our Intermediate dissection classes and we have not noted a single abnormality of this type. The specimen, described in the present paper, has lain in the Zoology Museum of our College, nobody can tell how long. Its label bears the legend " A freak of nature," but no data are available as to the locality from where it was obtained, the person who collected it, or the date of collection.

## 2. *Historical Résumé.*

As mentioned by O'Donoghue (1910), to whom I am grateful for much information about literature, Superville (1740) was perhaps the first to record a case of such abnormality, but he gave no more details than that the extra fore-limb was attached to the right shoulder. In 1864, Gervais described a specimen of *Pelobates cultripes* with a second left arm attached behind the normal one. In 1872, the Royal College of Surgeons catalogued a polymelous frog without sufficient details. In 1868, Lunel described an individual of *Rana viridis* with two supernumerary fore-limbs on the left side; a case similar to that described by Mazza in 1888 in *Rana esamelica*. In 1889, Bland Sutton noted a case of *Rana temporaria* with an extra fore-limb on the left side, while Bergendal described in detail a specimen of the same species showing similar abnormality. In 1899, Washburn noted an individual of *Bufo columbiensis* with an accessory arm anterior to the left normal one. In 1901, Johnson recorded a case of polymely in *Rana palmipes* and another

in *Rana halecinum*, while Eigerman and Cox described a specimen of *Rana pipiens* showing duplication of the right fore-limb. In 1910, O'Donoghue gave fairly detailed descriptions of two cases of polymely : one in *Hyla aurea*, in which the additional fore-limb was attached immediately in front of and slightly dorsal to the normal left arm ; and the second in *Rana temporaria*, in which the accessory arm was situated slightly dorsal and posterior to the normal right arm.

### 3. *External Features.*

The polymelous frog, which forms the subject of the present paper, measured 2·6 inches from snout to vent, and belonged to the species *Rana tigrina* Daud., as determined by reference to Boulenger's keys for this genus (1890, 1920). Amongst the characters observed, I might particularly mention the presence of several longitudinal folds on the skin of the back, the commencement of the oblique series of vomerine teeth from the inner anterior corner of the choanæ, the almost entire webbing of the toes, the possession of a perfectly distinct tympanum and the bluntly-terminated nature of the toes. The tibio-tarsal articulation did not reach the tip of the snout, the outer metatarsal tubercle was absent, and the inner was small, blunt and compressed. The colouration of the specimen had become much faded, owing evidently to long preservation in formalin, but a few dark patches and the yellow vertebral stripe were still discernible. The absence of the vocal sacs and of the pads on the inner side of the first fingers showed that the individual was female.

The additional fore-limb (Plate XXXIX) was present on the right side, and it was attached immediately anterior to—and at level with—the normal arm. It was a little longer even than the normal appendage, being about 1·4 inches from its attachment with the shoulder-girdle to the tip of the longest digit, and thereby exceeding the normal limb of this side by 0·2 inches. Its elbow-joint was distinctly marked, and it had four fingers, of which the second was the longest, the third smallest, and the first and fourth approximately equal. Dorsal to the point of attachment of the normal and the accessory right arms with the shoulder-girdle, there was on this side a definite hump, which felt hard to the touch.

The previous workers seem to imply that smaller size distinguishes a supernumerary limb from a normal one, and I myself was at first inclined to regard the smaller, posteriorly-situated of the two right fore-limbs in this specimen as really accessory, and the anterior one as the normal. A scrutiny of the proportionate sizes of the digits, however, left no doubt as to the true state of affairs. The digits on the posterior one of these appendages correspond to the typical arrangement found on the right side in the manus of

*Rana tigrina*, while those on the anterior one are really the exact *reverse* of this condition (Fig. 1, A, B and C).


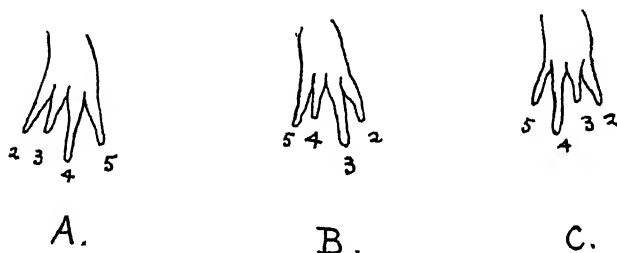
A.                    B.                    C.

FIG. 1.—Diagrammatic view of the hands of the abnormal Frog, as seen from the front: *A*, Left manus; *B*, Manus belonging to the anterior (Supernumerary) right fore-limb; *C*, Manus belonging to the posterior (normal) right fore-limb (Approximately ×I).

The following table gives the measurements for the various digits in this connection.

TABLE I.

*Comparative Sizes of Various Digits.*

| *Apparent* number of digit | Left manus | Anterior right manus | Posterior right manus |
|---|---|---|---|
| First (*i.e.*, the innermost) .. | 7 mm. | 6·5 mm. | 6 mm. |
| Second          ..          .. | 5 mm. | 8·5 mm. | 5 mm. |
| Third           ..          .. | 8 mm. | 5·5 mm. | 8 mm. |
| Fourth (the outermost)      .. | 7 mm. | 6·5 mm. | 6 mm. |

As is clear from this table, the *apparent* second (the *real* third) finger is the shortest both in the left manus and in the manus belonging to the posterior right fore-limb, denoting thereby that these limbs are the normal ones. This very digit is the longest in the manus of the anterior right fore-limb, thus corresponding to the apparent third finger of a normal manus. Thus the disposition of the fingers in the anterior right fore-limb (*i.e.*, in the limb regarded by me as supernumerary) is the same as would be found in a normal left fore-limb removed from the left side and transplanted to the right.

For the sake of comparison, one might quote the following description of the normal digits in the manus of the frog from Ecker and Haslam (1889) :—

" The hand has four fingers and the rudiment of a fifth, which latter is completely hidden under the skin, and as already explained, consists of a

metacarpal only. Of the four fingers, the fourth is the longest, the third the shortest, the second and fifth of intermediate and about equal length ; the fourth and fifth fingers have each three phalanges, the second and third have each two.'' This description refers more particularly to the species *Rana esculenta*, but it also fits in with the condition found in *R. tigrina*.

### 4. *Musculature.*

With reference to the polymelous specimen of *Hyla aurea* that he studied, O'Donoghue (1910) says, '' This specimen had been preserved for a long while so that it was very difficult to make out the musculature and as the whole arrangement is abnormal the naming is only approximate.'' He, however, mentions the names of some of the muscles that he found in it, as also in the polymelous individual of *Rana temporaria*, examined by him. Apart from this reference, as far as I am aware, Bergendal (1889) is the only person who has studied the musculature in a polymelous frog. In view of
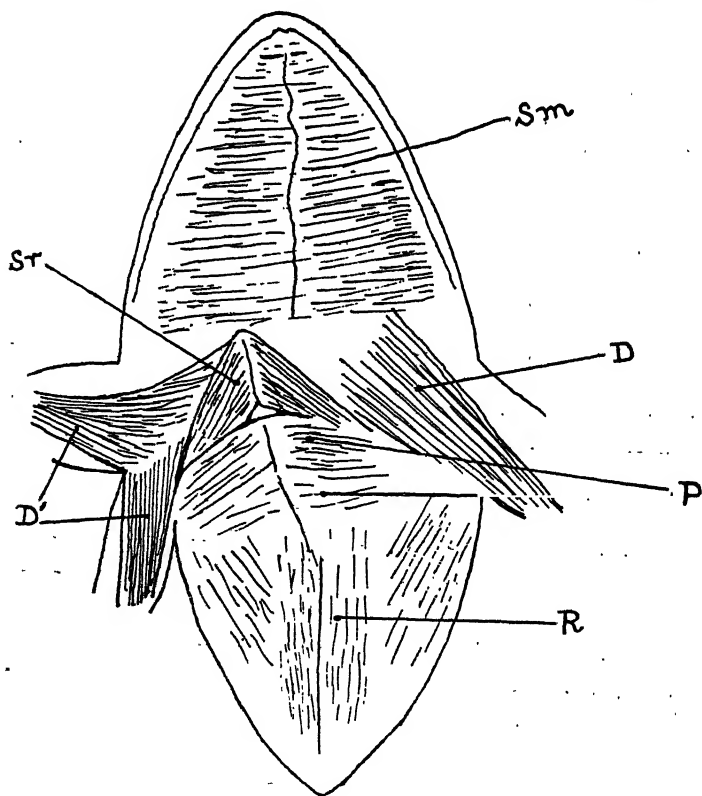


FIG. 2.—Muscles of the chest, throat and belly of the abnormal *Rana tigrina* : *D*, M. deltoideus (left) ; *D'*, M. deltoideus (right) ; *P*, M. pectoralis ; *R*, M. rectus abdominis ; *Sm.*, M. submaxillaris ; *Sr.*, M. coraco-radialis or sterno-radialis.

this paucity of information in this respect, I have been particularly careful to observe the various muscles in connection with the right fore-limbs in the present specimen, and my observations are given below.

On removing the skin from the ventral side of the trunk, it was clear (Fig. 2) that the line of origin of the muscle *Coraco-radialis*, Gaupp (= *M. sternoradialis*, Ecker; Pré-sterno-clavi-radial, Dugès) was not placed mid-longitudinally, but lay awry towards the right fore-limbs. The muscle *Deltoideus*, Gaupp and Ecker (= Pré-sterno-scapulo-huméral, Dugès), branched off into two divisions, one going into each of the two right fore-limbs. The *M. pectoralis* did not show any abnormality superficially besides its obliquely-placed line of origin. The musculature of the frog as seen in a lateral view (Fig. 3) confirmed my determination that the supernumerary limb was really the anterior one, the disposition of the various muscles in it being just the reverse of that found in a normal right fore-limb. A comparison of the musculature with Gaupp's Fig. 72 (p. 126), or Ecker and Haslam's 63 (p. 69), as well as with actual dissections of the normal right fore-limb of *Rana tigrina*, have left no doubt about my determinations. I wish only to draw attention here to the relation of the muscle *Anconæus*, Gaupp (= *M. triceps brachii*, Ecker; Scapulo-bi-huméro-olécranien, Dugès) to *M. deltoideus* and to *M. coraco-brachialis brevis* in order to show that the anterior fore-limb shows a reversed condition of musculature to that found in a normal limb of this side.
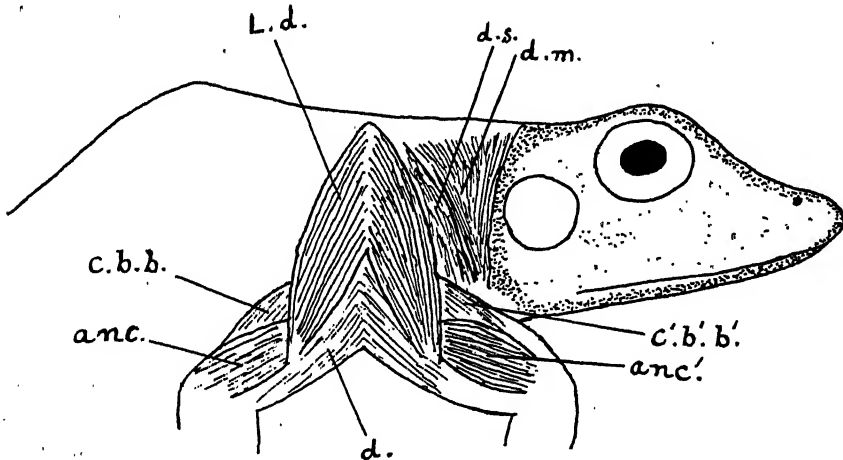


FIG. 3.—Muscles of the trunk of the abnormal *Rana tigrina*, from the right side : *anc., anc'.*, M. anconaeus; *c.b.b., c'.b'.b'.*, coracobrachialis brevis; *d*, M. deltoideus; *d.m.*, M. depressor mandibulæ; *d.s.*, M. dorsalis scapulæ; *l.d.*, M. latissimus dorsi [Names according to Gaupp, 1896].

The same type of reversal is found in the musculature of the arm belong-
ing to the anterior right fore-limb (Fig. 4, A), as compared either to the arm
of the posterior right fore-limb or to that found on the right side in a normal
individual of *Rana tigrina*. For the sake of comparison, the musculature of
the *normal* right arm of *Rana esculenta* from the same aspect is given in
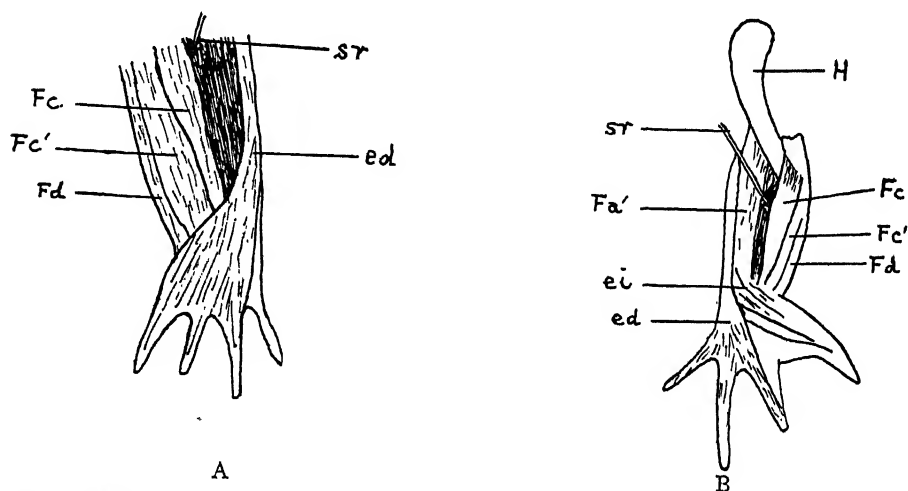Fig. 4, B.



FIG. 4.—Muscles of the right arm, from inner aspect : (A) Abnormal limb, *Rana tigrina* ; (B) Nor-
mal limb, *R. esculenta* (after Ecker). *ed.*, M. extens. digitorum communis ; *ei*, M.
abductor digiti II longus ; *Fa'*, M. flexor antibrachii lateralis superficialis ; *Fc*, M. flexor
carpi radial ; *Fc'*, M. flexor carpi ulnar ; *Fd*, M. flexor digitorum communis ; *Sr*, tendon of
the M. sternoradialis.

The remarkably well developed musculature on both the right fore-
limbs doubtless indicates that they were equally functional in life, though I
do not venture to suggest the actual mode of action of these limbs. I have
no doubt that the supernumerary limb reached to, and rested on, the ground,
both in view of the well developed palm and digits found on it, and of the
muscles that cannot be regarded as vestigial or rudimentary in any sense.

## 5. *Skeleton.*

As the present specimen shows notable differences in the skeleton of
the pectoral girdle from all the cases previously recorded, I have found it
advisable to summarise the pertinent data in this connection in the following
table.

TABLE II.

| No. | Name of author and year of publication | Species showing polymely | Brief description of supernumerary limbs | Skeletal peculiarities |
|---|---|---|---|---|
| 1. | Superville (1740) | Not known | Extra fore-limb attached to right shoulder. | . . . . |
| 2. | Gervais (1864) | *Pelobates cultripes* | Extra fore-arm behind normal left one. | A separate coracoid and scapula, a humerus and radio-ulna, fairly normal, and 3 digits, of which the two lateral were rudimentary, with but one phalanx each. |
| 3. | Royal College of Surgeons (1872) | . . . . | Extra fore-limb attached to sternum. | . . . . |
| 4. | Lunel (1868) | *Rana viridis* | A supernumerary pair of fore-limbs on left side. Fairly normal. | Each had a scapula. |
| 5. | Mazza (1888) | *Rana esamelica* | An additional pair of arms behind the normal left one. | The pair was attached to a separate shoulder-girdle formed by a single scapular & double coracoid portions. |
| 6. | Bland Sutton (1889) | *Rana temporaria* | Extra fore-limb on left side, with 3 digits. | Attached to left half of shoulder girdle by an extra coracoid (?) |
| 7. | Bergendal (1889) | *Rana temporaria* | Extra fore-limb on the left side. With only 2 digits. | A fairly normal humerus and radio-ulna. Humerus runs forwards under the skin of the floor of the mouth from the dorsal side of the coracoid, but does not appear to articulate with it. The remaining part of the limb comes through the skin and projects backwards. |
| 8. | Washburn (1899) | *Bufo columbiensis* | Extra arm in front of the left normal. With 7 digits. | According to the author, radius and ulna not fused, but separate. O'Donoghue (1910), however, is inclined to regard this as a case of " a double radio-ulna and a double hand". |
| 9. | Johnson (1901) | (1) *Rana palmipes* | A pair of extra fore-limbs, one on each side : Left fairly normal, but small; right previously cut off. | Normal scapular region. |
| 10. | Johnson (1901) | (2) *Rana halecinum* | Has a peduncle from which two extra fore-limbs arise ventral to the normal right one. Each about the size of the left normal leg and distinctly larger than the right normal leg. | |

TABLE II—(contd.)

| No. | Name of author and year of publication | Species showing polymely | Brief description of supernumerary limbs | Skeletal peculiarities |
|---|---|---|---|---|
| 11. | Eigerman and Cox (1901) | *Rana pipiens* | Has two fore-limbs on the right side. Extra limb fairly normal, but passes forward through a band of the skin of the floor of the mouth, being held as in a sling. Second, third and fourth digits normal; first double. | |
| 12. | O'Donoghue (1910) | (1) *Hyla aurea* | Extra fore-limb in front of and slightly dorsal to the normal left. Thin, but with a distinct elbow; its distal end apparently cut off and healed over. | Scapula inclined at an angle of about 30° to that normally evinced; an extra scapula attached to its dorsal edge, and is orientated differently. Humerus small, but fairly normal. Radio-ulna unusually bent, with a broken end. |
| 13. | O'Donoghue (1910) | (2) *Rana temporaria* | Extra arm slightly dorsal and posterior to the normal right. Thin, with the distal extremity ending in a blunt point. One digit. Joints apparently incapable of movement. | Shoulder-girdle normal, but for the presence of a shallow cavity on the dorsal edge of the glenoid cavity. Humerus small, immovably joined to an apparently single 'radio-ulna'. |

In the present polymelous specimen, the pectoral girdle is placed obliquely, being inclined at an angle of about 20° to the mid-longitudinal axis of the body. The left half of it is normal, and the humerus of the left fore-limb articulates with the glenoid cavity in the usual manner. On the right side, however, there are several remarkable deviations from the normal condition. The clavicle (Fig. 5) is distally single, but proxially it bifurcates to form a slender curved piece, which lies anterior to the right half of the girdle and is separated from the omo- and the epi-sternum by about 2 mm. There is an additional coracoid in connection with this clavicular piece, and the scapula shows two glenoid cavities: one posteriorly, which corresponds to the normal one, found on this side of the girdle; and the other anteriorly, which gives articulation to the humerus of the supernumerary limb. The portion of the scapula lying dorsal to the glenoid cavities is distinctly narrower than that in a normal girdle, being only 2·5 mm. broad all along, while this very portion on the left side is slightly more than 2·5 mm. even at the narrowest region. Unlike the left scapula, the right one is not a flattened piece, contracted in the middle, and wider at either end; but it is more or less cylindrical and is almost uniform in width above the glenoid cavities.
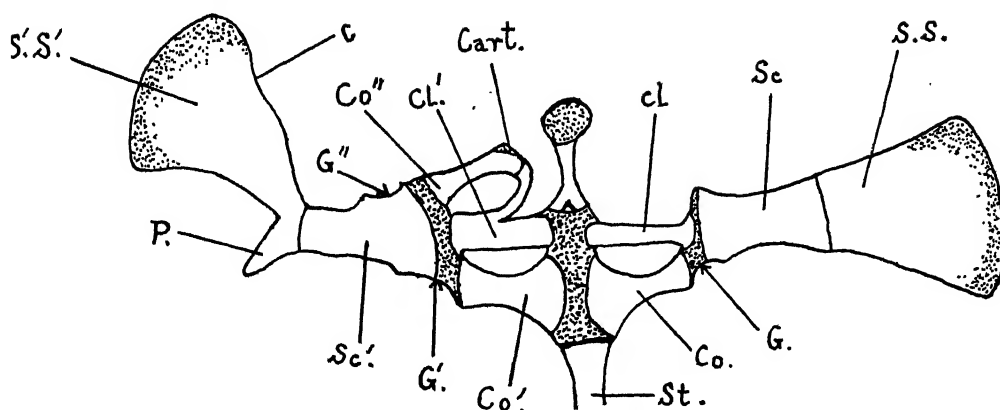
FIG. 5.—Shoulder-girdle and sternum of the polymelous frog *Rana tigrina*. Ventral view, twice natural size. *c*, unusual concavity on the anterior border of supra-scapula; *cart.*, cartilage at proximal end of extra coracoid; *Co*, left coracoid; *Co'*, right normal coracoid; *Co"*, right extra coracoid; *cl*, left clavicle; *cl'*, right clavicle, abnormally bifid; *G*, glenoid cavity (left); *G'*, right normal glenoid cavity; *G"*, glenoid cavity for extra fore-limb; *P*, abnormal posterior process of the right supra-scapula; *Sc*, *Sc'*, scapulæ; *S.S.*, left supra-scapula; *S'.S'.*, right supra-scapula; *st.*, sternum.

Between the two glenoid cavities, the scapula has a ridge dorso-ventrally on its outer surface.

The suprascapula of the right side also shows some peculiarities, worth noting. It has an abnormal posterior process, which diverges from its basal portion backwards, upwards and inwards, and ends in a blunt extremity. I have no doubt that the presence of this abnormal process was responsible for the appearance of the hard hump dorsal to the attachment of the two right fore-arms, which I have described in connection with the External Features (*vide supra*). The main part of the right suprascapula, which appears to correspond to the whole of a normal suprascapula, has its anterior border bent down on itself in the normal manner (Ecker and Haslam, 1889, p. 38), but this border shows an unusual concavity (*c* in Fig. 5) from a dorsal view and does not sweep away in a straight curve from its anterior end down to the anterior border of the scapula, as is usually the case.

I might also mention that contrary to the normal condition in *Rana tigrina*, as described by Nicholls (1915), the coracoids do not overlap in the middle line, but are separated from each other by the median epicoracoidal cartilage. The omosternum, however, is distinctly bifid posteriorly and thus shows the typical condition found in the Indian Bull-frog (Nicholls, 1915).

The supernumerary fore-limb (Fig. 6) has—but for the absence of the rudiments of the first real digit—a complete set of the usual bones: the

*humerus*, the *radio-ulna*, the *carpals*, the *meta-carpals*, and the *phalanges*. The apparent first and second digits (the real *second* and *third*) have three phalanges each, while the apparent third and fourth (the real *fourth* and *fifth*)
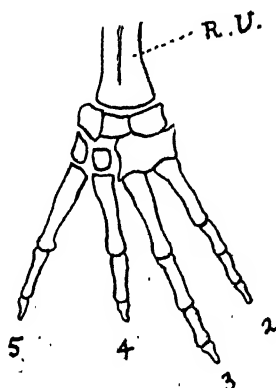


FIG. 6.—Bones of the fore-arm and the manus of the supernumerary limb. *R.U.* radio-ulna. The arrangement of the carpals is just the reverse of that found in a normal right hand.

have only two. The single metatarsal forming the vestiges of the first digit is totally absent. The number of phalanges in the respective digits confirms what has been said above about the correspondence of the various fingers of the accessory limb to those of a normal right one (*vide supra*).

### 6. Nerve-supply.

In the polymelous specimen of *Hyla aurea* described by him, O'Donoghue (1910) observed that the innervation of the supernumerary fore-limb was from an abnormal ganglion. "Anterior to and partially attached to the second spinal nerve, which supplied the left arm in a normal manner, was a slender nerve which after receiving a branch from the second spinal nerve, formed a noticeable ganglion. From this ganglion two nerves were given off which ran one to each side of the head of the abnormal arm and two other
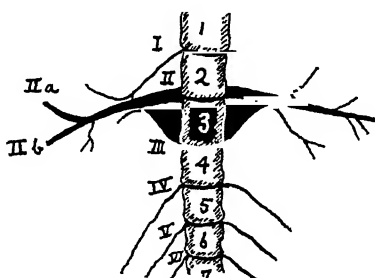


FIG. 7.—Anterior spinal nerves of the abnormal frog. The second spinal nerve (right side) bifurcates into two branches, II*a* and II*b*, to supply the two fore-limbs on this side.

Photograph of the abnormal frog
(Dorsal view).

smaller nerves were given off to the muscles around it." In the specimen of *Rana temporaria,* described by the same author, the accessory fore-limb was supplied by a large branch of the second spinal nerve.

The specimen of *Rana tigrina,* which forms subject of the present study, does not show any abnormal ganglion in connection with the brachial plexus. However, the second spinal nerve (Fig. 7) on the right side, unlike that on the left, bifurcates into two equi-sized branches, one going into each of the two right fore-limbs. The brachial plexus on the left side appears to be normal.

## 7.  Summary.

In the present study, observations have been made on a polymelous specimen of *Rana tigrina* Daud., the first abnormality of this type recorded for this species. Not only is a complete description of the external features given, but an examination of the correlated abnormalities in the muscular, skeletal and nervous systems has also been made. Apparently, the supernumerary right fore-limb shows a reversed condition to that found in a normal right fore-limb in this species.

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# ANTHROPOMETRY OF THE PRIMITIVE TRIBES OF TRAVANCORE.

By L. A. Krishna Iyer, M.A.

## Introduction.

THE Indian Empire comprises three main regions, the Himalayas or the abode of snow, the Middle land or Madhyadesa, as the river plains of Northern India are known in popular speech, and the southern tableland of the Deccan with its irregular high ranges rising out of undulating plains. Each region has its own peculiar characteristic ethnic character and has contributed a distinct element to the making of the Indian people. The Deccan forms one of the most ancient geological formations in the world and has, since the dawn of history, been the home of the aboriginal population. Travancore forms the south-westernmost part of the Deccan and bears the impact of all the racial migrations in the Deccan. It is protected by the Western Ghats on the east and the Arabian Sea on the west. Its total length from north to south is 174 miles, its width from east to west is 75 miles in the northern boundary and 30 miles at the southern extremity. It has an area of 7,625 square miles.

## Physical Features.

The physical features of Travancore are such that it can be divided into three distinct belts, each having its own characteristic soil, rainfall, vegetation, and cultivation. They are the Highlands, the Midlands, and the Lowlands. The Highland Division contains a low range of mountains with rich fertile lands at the foot, covered mostly with thick virgin forests. Most of the reserved forests are in this division and the portions thrown out for cultivation are covered with rubber, tea, and cardamoms. The rainfall ranges between 100 inches in the south and more than 200 inches in the north. Owing to the existence of reserved forests, the lands available for cultivation forms 34·6 per cent. of the total area. The cultivated portion is only 13·9 per cent. This region is most sparsely populated.

The Midland Division is higher in elevation than the Lowland and is dotted with low hills of varying sizes and shapes interspersed with long narrow valleys which are culitvated with paddy and the hill slopes and hills

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with cocoanut palm, topioca, pepper, ginger, rubber, and others. The rainfall varies from 55 to 140 inches. The soil is fertile.

The Lowland Division consists of flat stretches of lowlands lying along the coast at sea-level and composed mainly of recent deposits of sand or sandy loam, and is best suited for the cultivation of the cocoanut palm and paddy. The rainfall varies from 35 inches in the extreme south to 110 inches in the extreme north. Practically, the whole area is brought under cultivation.

### *Geographical Distribution of the Primitive Tribes.*

The Highland Region forms the home of the undernoted tribes :—

1.    Kānikkārs who are found in the forests of the Vilavancode, Neyyathumkara, Nedumangad, Pathanapuram, Shencotta, and Kottarakara Taluqs.

2.    The Malapantārams who are found scattered in the higher reaches of the Pamba and Achencoil rivers, and at Thalapara, and Kannapatti of the Shencotta Taluq.

3.    The Malavētans who are found both in the Midland and Highland taluqs of Pathanamthitta, Pathanapuram, Neduvangad, Chirayinkil, and Neyyathumkara.

4.    The Malankuravans who are found in the various parts of the State in the Highland and Midland divisions.

5.    The Ūrālis who are found in the Peermede and Thodupurzha Taluqs.

6.    The Paliyans who are found in the Peermede Taluq.

7.    The Mannāns who are found on the Cardamon Hills to the south of the Panniyar in the Peermede and Devikulam Taluqs.

8.    The Muthuvans who are found on the Kannan Devan and Cardamon Hills in the High Range Division.

9.    The Malapulayans who are found in Anjanad of Devikulam Taluq.

10.    The Vizhavans who are found in the Idyara valley of North Travancore.

The Midland region forms the home of the undernoted tribes :—

1.    The Malayarayans who are found in the forests of Changanaseri, Minachil, and Thodupuzha Taluqs.

2.    The Ullātans who are found in the Rāni reserve in the Highland region and in various parts of Midland region.

3.    The Parayans who are found throughout this region.

4.    The Pulayans who are found in the central and northern taluqs of Travancore.

5. The Nāyādis who are found in North Travancore.

In the Lowland region, the Thantapulayans are found. The Pulayans are also found in this region.

*Population.*

The primitive tribes were returned at the Census of 1931 as 128,838, of whom 115,151 are Hindus, 10,780 Christians, and 2,907 belong to Tribal Religions. A comparison of the figures at different censuses can be made to demonstrate the process of rapid Hinduization that is taking place among these primitive tribes. The number of animists returned in 1901 was 28,193. It went down to 15,773 in 1911, to 12,637 in 1921, and to 2,097 in 1931. The only inference that can be drawn is that the animists are being depleted and the numbers they lose the Hindus gain largely and Christians to a small extent. "The opening of a large number of estates in forest regions has

TABLE I.

| No. | Name of Tribe | Hindu | Christian | Tribal Religion | Total |
|---|---|---|---|---|---|
| 1 | Kānikkāran | 4,565 | 53 | 2,041 | 6,659 |
| 2 | Kuravan | 87,071 | 8,158 | 66 | 95,295 |
| 3 | Malankuti (Vishavan) | 166 | .. | .. | 166 |
| 4 | Malapantāram | 100 | .. | 87 | 187 |
| 5 | Malapulayan | 254 | .. | .. | 254 |
| 6 | Mala-Ūrāli | 846 | .. | 70 | 916 |
| 7 | Malayarayan | 2,807 | 255 | 120 | 3,182 |
| 8 | Mannān | 1,215 | .. | 61 | 1,276 |
| 9 | Muthuvan | 1,238 | .. | 63 | 1,301 |
| 10 | Nāyādi | 144 | .. | .. | 144 |
| 11 | Paliyan | 379 | 23 | 81 | 483 |
| 12 | Thantapulayan | 795 | .. | .. | 795 |
| 13 | Ullātan | 4,824 | 220 | 77 | 5,121 |
| 14 | Vētan | 9,496 | 2,000 | 241 | 11,737 |
| 15 | Vēttuvan | 1,251 | .. | 71 | 1,322 |

provided facilities for their coming in contact with the people of the plains. Some of the tribes are coming down the plains to earn their livelihood.  In this way as well as by the penetration of civilized man in the forests, the primitive tribes are being brought under the influence of the Hindus and the Christian missionaries."[1]  A statement of their population  as they stood in 1931 is given in Table I.

### Effects of Geographical Environment.

The geographical conditions of Travancore are such that the primitive tribes have had to live "in regions of plenty to-day and poverty to-morrow ". Of all the tribes, the Malapantārams, the Muthuvans, and the Ūrālis have been least affected by outside influences.  The remaining tribes have been subject to extraneous influences, and have therefore received an infusion of foreign blood and new ideas  from  the  more  civilized  people  with  whom they have come into contact.   This is clearly seen in the Vishavan, the Paliyan, the Ullātan, the Malayarayan,  the Mannān, and  the Kānikkāran. Owing to the admixture of foreign blood, these tribes are now approaching the composite type of civilized humanity.

Climate determines the crop that man can grow in a locality.   The Mannān, the Muthuvan, the Paliyan,  and the Malapulayan who are found on an altitude of 2,000 to 5,000 feet above sea-level, cultivate ragi, while the Kānikkāran, the Malayarayan, the Ullātan, the Vishavan, and others who live on lower elevations cultivate paddy and tapioca.   Where climate favours the growth of forests, there it prolongs the hunter stage of development and retards the advance to agriculture.  The Malapantāram is the only tribe in Travancore in the hunter stage.

The salubriety of high altitudes is favourable to human development. We see it exemplified in the Muthuvans, the Mannāns, the Paliyans, the Ūrālis, and the Malapulayans and the Malapantārams. Their well-developed lungs, massive chests, large torsos are due to the influence of the rarefied air at the high altitude in which they live.   The average chest girth of the primitive tribes is given in Table II.

The backwardness of tropical countries is said to be due to excessive heat.   Intense heat of long duration combined with a high degree of humidity is unfavourable to human development.   It brings about inervation, creates a craving for stimulants, and induces habits of alcoholism.   Further, malaria is a disease of tropical and sub-tropical countries whose climate is characterised by wet and dry seasons.   A people devitalised by this disease cannot be expected to be energetic and active.   The Kānikkār, the Ullātan, the Vishavan, and Malavētan are good examples of devitilization caused by tropical illness and they have the lowest average chest girth.

TABLE II.

| No. | Name of Tribe | Average Circumference of Chest in Cm. |
|---|---|---|
| 1 | Muthuvan | 77·1 |
| 2 | Mannān | 75·8 |
| 3 | Malapulayan | 78·9 |
| 4 | Malapantāram | 77·6 |
| 5 | Malankuti | 77·2 |
| 6 | Ūrāli | 75·5 |
| 7 | Malayarayan | 77·3 |
| 8 | Kānikkāran | 74·8 |
| 9 | Malavētan | 74·0 |
| 10 | Ullātan | 73·8 |
| 11 | Malankuravan | 73·8 |
| 12 | Paliyan | 75·0 |
| 13 | Pulaya | 74·7 |
| 14 | Thantapulaya | 76·8 |

*Anthropometric Work in India.*

Anthropometry was first introduced in India by Sir Herbert Risley in his Ethnographic Survey of Bengal. It was the first attempt to apply to Indian Ethnography the methods of systematic research sanctioned by the authority of European anthropologists. Among these, the measurements of physical characters occupy a prominent place. " Nowhere else in the world do we find the population of a large continent broken up into an infinite number of exclusive aggregates, the members of which are forbidden by the inexorable social law to marry outside the group to which they themselves belong. Whatever may have been the origin an earlier development of caste, the absolute prohibition of mixed marriages stands forth now as its most essential and prominent characteristic and the feeling against such unions is so deeply engrained. In a society putting an extravagant value of

the pride of blood and the idea of ceremonial purity, differences of physical type may be expected to manifest a high degree of persistence."[2]

Travancore is one of the most caste ridden States of India, and the remarks exactly fit in to it. According to Risley, analysis of data collected by him among 89 tribes and castes of Bengal and the United Provinces of Agra and Oudh rendered it possible to distinguish three types, the Aryan, the Mongolian, and the Dravidian. This classification was, at the time, accepted by Flower, Beddœ, and Haddon in England, and Topinard in France. Great additions have since been made to the number of measurements on living subjects by Edgar Thurston, Holland, Dr. Guha, Dr. Eickstedt, Dr. Macfarlane, Signor Cipriani, and by the writer in Travancore. Risley's work remains and forms "the key stone of anthropological research in India". The Census Report of 1901 laid the foundations on which has been since based all work that has been done on the racial composition of India. The results of such work . during the last 30 years have so far changed the whole complexion of the problem that a restatement of the whole position is now required, and his conclusions require revision. He recognized three main racial types in India, the Dravidian, the Indo-Aryan, and the Turko-Iranian, the latter of which was confined to North-West Frontier and the two former of which were modified by two subsidiary elements, the Scythian and Mongolian respectively by introducing the brachycephalic elements found in Eastern and Western India. According to Dr. Hutton, "Risley's deductions were coloured by an erroneous belief in the racial composition of India. In any case, it is necessary to clear the deck by throwing overboard some of his deductions. The Dravidian as conceived by him, has been the first to go, and has been replaced by at least three races, where he recognised only one."[3]

The material available for the determination of the racial elements and affinities of the Indian peoples may be divided into physical, linguistic, and cultural features. According to Sir William Fowler, physical characters are the best, in fact, the only true tests of race, that is of real affinity ; language customs, and others may help or give indications, but they are often misleading. It was Sir Henry Maine who first said that the study of the sacred languages of India has given the world the modern science of Philology and the modern theory of race. The belief that linguistic affinities prove community of descent was one which commended itself alike to population struggling for freedom and to rulers in search of excuses for removing a neighbour's landmark. According to Sayce, identity or relationship of language can prove nothing more than social contact.

B5                                                                                      F

*Physical Characters.*

Coming to physical characters, they are of two kinds, definite and indefinite. The indefinite characters include colour, texture of skin, the colour, form, and position of the eyes, the colour and character of the hair, and the form of the face and features.

*Colour of the Skin.*

The skin exhibits extreme divergence of colour and serves with hair as a classical basis of distinction of human races. Anthropologists are agreed that primitive men were much alike and were dark in colour. It is said that colouration of the skin is the conjoint effect of a number of environmental factors working through physiological processes. The pigment of the skin is found in the epidermis, and the influence of light favours its formation. In a cold climate where thermal action is weak, a discolouration of the pigment in the skin and other parts of the body produces a kind of albinism. The Kānikkār, the Ullātans, and the Malayarayans who live at low elevations are darker than the Muthuvans, the Mannāns, and the Paliyans of the High Ranges. Blondness increases appreciably on high hills. "Waitz long ago affirmed the tendency of mountaineers to lighter colouring from his study of primitive peoples. This may not be entirely due to climatic contrast between mountain and plain. Economic poverty of the environment and poor food supply have also a hand."[4] Finot thinks that colour is the direct effect of the 'mileau'. "Woodroff concludes that man is invariably coveted with a pigment which acts as an armour to exclude the more harmful short rays and moreover the amount of pigment is in direct proportion to the intensity of light of the country to which his ancestors have proved their adjustment by centuries or millenniums of survival of health and vigour."[5] The Thantapulayans who live in the vast expanse of sand along the coastal region, and the Pulayans, and the Parayans who work in the rice fields throughout the day are jet black in complexion.

*Hair.*

From one end of India to the other, the hair of the great mass of the population is black or dark brown. The Kānikkār have curly hair. "The Ūrālis have also very curly hair which is also harsh and in some individuals crisp and kinky."[6] Curly hair has been noticed by me among the Malavētans, the Vishavans, the Ullātans, the Malapantārams, and the Paliyans. The hair curls on itself that it seems to grow in separate spiral tufts. Dr. Guha has observed the existence of frizzly hair among the Kadars and the Pulayans of the Cochin State.[7] Dr. Hutton has recently drawn attention to the

presence of the Negrito type among the Angami Nagas.[8]  To him, the Urālis seem to suggest the Negrito as much as the Kadar does.

The eyes are invariably dark brown.  It is highly probable that ' brown ' was the primitive eye colour in man.  The brown colour seems to have been retained, as it affords protection for the eye against the strong rays of the sun.  Rare cases of albinism are noticed among the Kānikkār.  Such men have white skin, yellow hair, and dark blue iris.

### *Definite Characters.*

1.  *Stature.*—Three characters are selected under the head. They are the stature, the proportions of the head, and the nose.  Darwin holds that "changes such as size, colour, thickness of skin, and hair have been produced through food-supply and climate from the external conditions in which the forms lived. " Stature," according to Semple, " is partly of feeding and hence of geographical  conditions."[9]  In Travancore, the primitive tribes are generally on the hills shorter than those of the plains ; but within the hilly regions, " stature is often larger at high than at moderate latitudes, which is ascribed to the influence of rigorous climate in killing off all but vigorous individuals."[10]  Sir Arthur Keith says that "the greater activity of the pituatory gland gives the Caucasian his height of stature, bulk of body, prominent chin, strong eye-brow ridges, and pronounced nasaliza-tion."[11]  Improvement in the quality or abundance of food or the con-ditions have been supposed to lead on the other hand to increase of stature.[12]  This may be true of the Malayarayans, the Muthuvans, the Ūrālis, and others.  The average stature of the primitive tribes of Travancore is given in Table III.

The greater height of the Malapulayans, the Paliyans, the Muthuvans, the Mannāns, and the Ūrālis may be due to the more rigorous functioning of the pituatory gland at higher elevations.  " Excessive tallness is the result of inherited excessive activity of the pituatory gland, the factors for tallness being mostly recessive due to the absence of inhibition to prolonged growth."[13]  Davenport says that " the rugged hills of Scotland harbour a race that are relatively giants.  Conditions in life cannot account for the difference, there is a difference in blood."[14]  The High Ranges of Travancore whose elevation ranges from 3,000 to 5,000 feet above sea-level harbour the Malapulayans, the Paliyans, the Ūrālis, the Muthuvans and the Mannāns, who are taller than the tribes in low country who are devitalised by the presence of malaria.  According to Topinard's classification of stature, those who are below 160 cm. (5' 3") are classified as short.  Judged by this standard, all the primitive tribes of Travancore except the Malapulayans are short.  The effect of a

TABLE III.

| No. | Name of Tribe | Number Measured | Stature in Cm. |
|---|---|---|---|
| 1 | Paliyans | 21 | 159·3 |
| 2 | Malapulayans | 33 | 161·0 |
| 3 | Mannān | 10 | 157·7 |
| 4 | Muthuvan | 36 | 157·3 |
| 5 | Malayarayan | 133 | 157·1 |
| 6 | Malapantāram | 19 | 156·6 |
| 7 | Ūrāli | 108 | 156·0 |
| 8 | Vishavan | 21 | 155·8 |
| 9 | Ullātan | 83 | 154·5 |
| 10 | Malankuravan | 83 | 154·2 |
| 11 | Malavētan | 63 | 153·3 |
| 12 | Pulayan | 54 | 153·9 |
| 13 | Thantapulayan | 38 | 152·3 |
| 14 | Kānikkār | 189 | 152·9 |

scanty and uncertain food-supply is seen in the low stature of the Kānikkār, the Pulayan, the Malavētan and the Malankuruvan.

*Shape of the Head.*—According to Risley, the prevalent type of Peninsular India seems to be long-headed, short heads appearing only in the western zone of the country. The primitive tribes of Travancore are long headed with one exception, and their average cephalic index is given in Table IV.

The dolichocephaly of the primitive tribes is of a primitive type, for the vault of the head is low and the direction of the brain backward. They occasionally show a prognathous face. The Malapantārams are alone mesocephalic. Out of 63 men and women measured, 66·7 per cent. was mesocephalic, and 6·3 per cent., brachycephalic. It is considered that the basis of the Negrito race was probably brachycephalic or at least meso.

TABLE IV.

| No. | Name of Tribe | Number Measured | Average Cephalic Index | Average C. I. given by Thurston |
|---|---|---|---|---|
| 1 | Malavētan .. .. | 63 | 73·5 | 73·4 |
| 2 | Malankuravan .. | 83 | 74·1 | |
| 3 | Kānikkār .. .. | 189 | 74·2 | 73·4 |
| 4 | Muthuvan .. .. | 70 | 73·8 | |
| 5 | Ullātan .. .. | 83 | 73·8 | |
| 6 | Ūrāli .. .. | 108 | 71·7 | 74·6 |
| 7 | Malapulayan .. .. | 33 | 74·4 | |
| 8 | Pulayan .. .. | 54 | 73·9 | |
| 9 | Paliyan .. .. | 21 | 74·4 | 75·7 |
| 10 | Malayarayan .. .. | 133 | 73·4 | |
| 11 | Vishavan .. .. | 21 | 74·0 | |
| 12 | Mannān .. .. | 43 | 74·1 | |
| 13 | Thantapulayan .. | 38 | 74·0 | |
| 14 | Malapantāram .. | 63 | 76·0 | |

The Malapantārams are in the hunting stage of civilization. 27 per cent. are now dolichocephalic. According to the definition of Quatrefage, the Negritos are brachycephalic. It seems that admixture with a primitive dolichocephalic race has effected the general shape of the head. They have curly hair. They may be the survivals of a Negrito type.

*Nasal Index.*—Risley finds in India that the nasal index ranks higher as a distinctive character than the stature or even the cephalic index itself. The nasal index is accepted by all anthropologists as one of the best tests. "According to Topinard, there are two types of human nose, the low, broad, and flat. As a rule, the more prominent a nose is, the narrower it is ; the flatter it is, the broader it becomes. The depth increases with the prominence,

and narrows and diminishes with the flattening and broadening."[15] The Rig-Veda employs the word 'anasa' or noseless to the Dasyus which designations mean 'Thieves' or 'demons'. The broad type of nose of the primitive tribes is their striking characteristic. The physical configuration of the country, the vast stretches of fever-haunted jungles, the absence of roads and the complete social organisation of the primitive tribes protect them from the intrusion of foreign influence. Where races with different nasal proportions are intermixed, the index marks the degree of crossing that has taken place. The average nasal index of the following tribes is given in Table V.

TABLE V.

| No. | Name of Tribe | Number Measured | Average Nasal Index | Measurements of Dr. Thurston | |
|---|---|---|---|---|---|
| | | | | Index | Number Measured |
| 1 | Malavētan　　.. 　.. | 63 | 92·4 | 84·0 | 25 |
| 2 | Malankuravan　　.. | 83 | 90·6 | | |
| 3 | Kānikkār　　..　.. | 189 | 89·6 | 84·6 | .. |
| 4 | Muthuvan　　..　.. | 70 | 88·4 | | |
| 5 | Ullātan　　..　.. | 83 | 88·4 | | |
| 6 | Ūrāli　　..　.. | 108 | 86·4 | 80·1 | 57 |
| 7 | Malapulayan　..　.. | 33 | 86·0 | | |
| 8 | Vishavan　　..　.. | 75 | 88·0 | | |
| 9 | Pulayan　　..　.. | 54 | 84·4 | | |
| 10 | Paliyan　　..　.. | 21 | 84·1 | 83·0 | 26 |
| 11 | Malayarayan　..　.. | 133 | 84·0 | | |
| 12 | Mannān　　..　.. | 43 | 82·7 | | |
| 13 | Malapantāram　　.. | 63 | 78·2 | | |
| 14 | Thantapulayan　　.. | 38 | 78·1 | | |

The Malavētan, the Malankuruvan, the Kānikkār, the Muthuvan, the Ullātan, the Ūrāli, the Malapulayan, and the Vishavan have distinctly platyrhine

nose, while the Pulayan, Paliyan, and the Malayarayan border on platyrhiny. The remaining tribes are mesorhine. To sum up, short stature, low forehead, flat nose, and dark complexion are the characteristic features of the primitive tribes of Travancore.

The above data collected by me enables me to make a clear racial study of the primitive tribes of Travancore. When Ctesias speaks of the small stature, black complexion and snub noses of India, we feel that the description is precise enough to enable us to study them with the Dasyus and Nishadas of early Sanskrit Literature. The *Bhagavatha Purana* describes Nishada as " black like crows, very low statured, high cheek bones, low-topped nose, red eyes, and copper coloured hair."[16] His descendants are distributed over the hills and forests. The Anamalai Hills of Southern India form the refuge of a whole series of broken tribes who are characterised by dark complexion, low stature, and flat nose. Who are these Nishadas ?

The Nishadas were reckoned by Sir Herbert Risley as belonging to the ' Dravidian race,' occupying the oldest geological formation in India, the medley of forest-clad hills, terraced plateau, and undulating plains which stretch from the Vindhyas to Cape Comorin. He is recognised everywhere by his black skin, his squat figure, and the Negro-like proportions of the nose. Risley looked to the researches of Thurston to define and classify the numerous sub-tribes. " In describing the Hindu type, Topinard divides the population of the Indian Peninsula into three strata, the Black, the Mongolian, and the Aryan. The remnants of the first are found at the present time shut up in the mountains of Central India under the names of Bhils, Mahairs, Gonds, and Khonds ; and in the south under of Yānadis, Maravars, Kurumbas, and Veddahs. Its primitive characters apart from its dark colour, and low stature are difficult to discover, but travellers do not talk of woolly hair in India."[17] Mr. Thurston continues that there is much that speaks in favour of the view " that the Australians and the Dravidians sprang from a common main branch of the Human race. The Veddahs of India and Ceylon, whom one might call Pre-Dravidians, would represent an offshoot of the main stem. Southern India was once the passage ground by which the ancient progenitors of Northern and Mediterranean races proceeded to the parts of the globe which they now inhabit. In this part of the world as in others, antiquarian remains show the existence of peoples who used successively implements of unwrought stone, of wrought stone, and of metal fashioned in the most primitive manner. These tribes have also left cairns and stone circles indicating burial places. It has been usual to set them down as earlier than Dravidian. It has been stated that the wild tribes of Southern India are physiologically of an earlier type than the Dravidian tribes."[18]

Sergi rightly separates from the Dravidians a highly platyrhine type and of a stature less than of medium type showing the greatest affinity with the Veddahs, and together with the second type he also perceives a third in the Peninsula especially among the Kadars, which type is also platyrhine, and of a low stature, but with short and woolly hair and a Negroid face. They are the remnants respectively of the Australoids and the Negritos who were afterwards more closely placed in relief by Biasutti. The following ethnic stratification is given for India[19]:—

1.   Negritos.
2.   Pre-Dravidians.
3.   Dravidians.
4.   Tall dolichocephalic (Mesopotamic) elements.
5.   Dolichocephalic Aryans.
6.   Brachycephalic Leucoderms.

" Our theory is that the Dravidians are Australoid-Veddahs and are not to be confused with an oriental extension of the Mediterranean race which Risley thinks or with Elliot Smith a Brown race whose anthropological consistency is somewhat equivocal. It would be useful to see what physical characters are presented by the prehistoric skulls of India, especially of the Bayana type which Mr. Mitra refers to as of Pre-Dravidic Veddah type, and those of Adichanallur, which, according to Lapieque, but in a different sense from others, i.e., rather Negroid."[20]   The Pre-Dravidians were followed by a finer type, although dark skinned, the nose was less wide, and so deep at the root as in the Veddahs, and the profile much less prognathous, really almost orthognathous.   It is the Dravidian type akin to the Ethiopian (not Negroid).

If we arrange a series of measurements of the jungle tribes in the order of descending nasal index, it may be seen that, as we advance from platyrhiny to mesorhiny, there is an increase in the proportion per cent. of the Dravidian type, which we considered mesorhine.

I give below the results of my study based on extensive measurements of the primitive tribes of Travancore (Tables VI and VII).

TABLE VI.

| No. | Tribe | No. | Stature | Cephalic Index | Nasal Index | Remarks |
|-----|-------|-----|---------|----------------|-------------|---------|
| 1 | Paniyan .. .. | 25 | 157·4 | 74·0 | 95·1 | |
| 2 | Kadir .. .. | 23 | 157·7 | 72·9 | 89·8 | |
| 3 | Kuruba .. .. | 22 | 157·9 | 76·5 | 86·1 | |
| 4 | Sholaga .. .. | 20 | 159·3 | 74·9 | 85·1 | |
| 5 | Irula (Nilgris) .. | 25 | 159·8 | 75·8 | 84·9 | |
| 6 | Malavētan .. | 25 | 154·8 | 73·4 | 84·6 | |
| 7 | Kānikkār .. .. | 20 | 155·2 | 73·4 | 84·6 | |
| 8 | Paliyan .. .. | 26 | 150·9 | 75·7 | 83·0 | |
| 9 | Ūrāli .. .. | 57 | 159·5 | 74·6 | 80·1 | |

*Typical Tribes of Homo Indo-Africanus*

| No. | Tribe | No. | Stature | Cephalic Index | Nasal Index | Remarks |
|-----|-------|-----|---------|----------------|-------------|---------|
| 1 | Kota .. .. | 25 | 162·9 | 74·1 | 77·2 | |
| 2 | Badaga .. .. | 40 | 164·1 | 71·7 | 75·6 | |
| 3 | Kuruba of Mysore .. | 50 | 163·6 | 77·3 | 73·5 | |

TABLE VII.

| No. | Name of Tribe | No. | Stature | Cephalic Index | Nasal Index | Remarks |
|-----|---------------|-----|---------|----------------|-------------|---------|
| 1 | Malavētan .. | 63 | 153·3 | 73·5 | 92·4 | |
| 2 | Malankuravan .. | 83 | 154·2 | 74·1 | 90·6 | |
| 3 | Kānikkār .. .. | 189 | 152·9 | 74·2 | 89·6 | |
| 4 | Muthuvan.. .. | 70 | 154·2 | 73·8 | 88·4 | |
| 5 | Ullātan .. .. | 83 | 154·5 | 73·8 | 88·4 | |
| 6 | Ūrāli .. .. | 108 | 156·0 | 71·7 | 86·3 | |
| 7 | Malapulayan .. | 33 | 161·0 | 74·4 | 86·0 | |
| 8 | Paliyan .. .. | 21 | 159·3 | 74·4 | 84·1 | |
| 9 | Malayarayan .. | 133 | 157·1 | 73·4 | 84·0 | |
| 10 | Vishavan .. .. | 21 | 155·8 | 74·0 | 83·8 | |
| 11 | Mannān .. .. | 43 | 154·5 | 74·1 | 82·9 | |
| 12 | Malapantāram .. | 63 | 154·7 | 76·0 | 78·0 | |
| 13 | Pulayan .. .. | 54 | 153·9 | 73·9 | 84·6 | |
| 14 | Thantapulayan .. | 38 | 152·3 | 74·0 | 78·1 | |

Comparing the two summaries, one can understand at a glance how the intercrossing of the jungle tribes with Dravidian tribes has the effect of diminishing the platyrhine feature as seen among the Tamil Irulans whose nasal index comes down to 80·4. Thurston expressly notes the physical change that takes place, when the tribes leave the jungle and approach the

cities. His observations on the nasal index of the Kānikkār are given in Table VIII.

TABLE VIII.

| Type | Average Nasal Index | Maximum Nasal Index | Minimum Nasal Index |
|---|---|---|---|
| Jungle ..        .. | 84·6 | 105 | 72·3 |
| Domesticated ..        .. | 81·2 | 90·5 | 70·8 |

It may be seen that the nasal index of the jungle Kānikkār is higher than that of the domesticated Kānikkār of the plains. This is an instance of primitive short, dark-skinned, and platyrhine type changing as a result of contract metamorphosis towards leptorhiny. A great elevation in nasal index is observed among the tribes of Chota Nagpur and Western Bengal. " Biasutti includes their habitat in the area where a purer Veddaic substratum has persisted. Denikar recognizes that the Veddahs are the remnants of a very primitive population, whose physical type is most approached by a platyrhinous variety of the Dravidian race thus indicating precisely the Santals, the Mundas, the Kola, and the Bhumij. We prefer to confine the Dravidian race to the mesorhine type. In such manner, we confer on the Pre-Dravidians the present numerical preponderance and their importance in the ethnical stratification of India augments proportionately."[21]

Dr. Eickstedt has thrown new light on the ethnical composition of India. According to him, the most primitive racial stratum are the Weddids. They probably number over 20,000,000, and only a century ago, formed one-third of the whole population of India. The Gondids and the Malids are the most important sub-types. The Gondid race is chiefly characterised in the widely spread Gond tribes of Central India. The Malids from the southern sub-type of the Weddids. The type is here more primitive than among the Gondids. In the case of many individuals, the face is extremely low and lozenge-shaped. This shape is the consequence of very wide jaw bones and pointed chin. The chin moreover is small, and its profile, particularly in the case of women, extremely retreating. The nose is very broad and low, the steep forehead often overhangs the eyes. The lips are fairly thick, at any rate thicker than is the case with the Gondids. Quite often, the face is lightly prognathous. They are extremely dark-skinned, indeed almost black-brown. Dr. Eickstedt's view is not correct without more ado to associate the Malids with the Negritos (as has been done by Lapicque and Keane).

Negritos are indeed of small stature even very much more smaller than the Malids, and they have dark skins and curly hair, but they indeed by no means reveal the primitiveness of the Malids. It would be more cautious and more correct to assume the existence of a Proto-Negrito element and its fusion into the ancient Indian Weddid aborigines. Dr. Eickstedt thinks that "this standpoint does not differ very materially from that of Keane, but signifies a deepening and differentiation of our view, as must be expected with our advance of knowledge."[22] According to him, "the Malids are only found in the southern forest areas of India. They form a thick band running northwards from the southernmost Cardamon Hills to the Nilgiris splitting up here and continuing on the one hand as far as some uncertain northern limit in the west Mysore forests and over the Nallamalais as far as Krishna. Kānikkār, Malabedar, and Kurumber are characteristic groups in the west, and Irular, Yanadi, Chenchu, etc., in the east."[23]

### The Negrito Element in Travancore.

The presence of a Negrito strain in the aboriginal population of South India was suspected by early observers, but definite evidence was lacking. Its existence among the Kadars of the Cochin State was several times advanced by Preuss, Keane, Sergi, and Haddon. The researches of Lapicque among the Kadars convinced him that the existence of ' une race nigre primitive ' was incontestable.

Dr. Hutton has drawn attention to the presence of the Negrito type among the Angami Nagas and says, " In the Kadars and the Ūrālis of the extreme south, occasional individuals with frizzly hair and low stature and negro-like features are very suggestive of survivals of the Negrito race."[24] " To Dr. Hutton, the Ūrālis seem to suggest the Negrito as much as the Kadar does. The height of the men is about 5 feet, the hair is very curly, but is also harsh and in some individuals crisp and kinky. The features suggest that the basic type is Proto-Australoid with some admixture of Negrito and perhaps Mediterranean. The Kānikkār are also described by him as Proto-Australoid with also some Negrito admixture and being by no means pronouncedly prognathous.[25] Spirally curved hair has been observed by me among the Ūrālis, the Kānikkār, the Malapantārams, the Malavētans, and the Vishavans.

Dr. Guha observed the existence of frizzly hair among the Kadars of the Cochin State. According to him, the comparatively low values of the C. R. I. found between the Kadar and the Nattu Malayan, and the Yeruva, and their divergencies from the Bhil-Chenchu type, coupled with the distinct negroid features in many of the individuals belonging to these tribes, seem also due to the Negrito strain among the latter, though it may appear to

be submerged at the present moment. It has therefore to be inferred that the remnants of the Negrito race now found among Semangs and the Andamanese were much more widely spread at one time and extended well into the Indian Continent to the southwesternmost end in Cochin and Travancore.

It was Quatrefage who laid down that the Negritos are brachycephalic. Dr. Guha observes, "though the mean cephalic index of the Kadars was dolichocephalic, among the individuals with frizzly hair, there was a marked tendency for a rise in the index towards mesorhiny as shown by two individuals having 77·34 and 79·29 as the values of their index which indicated that the basis of the Negrito type was probably brachycephalic or at least meso as in the Semangs, but large admixture with the primitive dolichocephalic race has affected the general shape of their head. He also thinks that the long spirals now seen among most of the Kadars and Pulayans with frizzly hair was probably due to the same admixture. He observed short spirals in two individuals. At the present day, the Negritos are found to be closely similar to the Melanesian type in hair and head form, but judging from the presence of two men with short spirals and high cephalic index, Dr. Guha is of opinion that the original type was not probably unlike that of the Semangs and Andamanese, among whom designs of bamboo combs identical with those used by the Kadar women are found.[26]

In Travancore are found the Malapantārams, a jungle tribe in the hunting stage of civilization. In 1935, I measured 63 individuals of whom 17 were dolichocephalic, 42 mesocephalic, and 4 brachycephalic. Their forehead is receding, and brow-ridges are prominent. The hair is black and looks curly in some. Their average cephalic index is 76·0. The value of the cephalic index of the Malapantārams goes to confirm the theory that the basis of the Negrito type was probably brachycephalic or at least meso as in the Semangs, but that large admixture with the primitive dolichocephalic race has affected the general shape of the head.

The presence of a Negrito strain in the aboriginal population of South India thus receives additional testimony from its existence among some of the primitive tribes of Travancore, where it has been observed by Dr. Hutton and myself. The photographs will bear ample evidence to it. The Negrito appears to have been the first inhabitant of South Eastern Asia.

Traces of his stock are still to be seen in some of the forest tribes of the higher hills of the extreme south of India and similar traces appear to exist in the inaccessible areas between Assam and Burma, where a dwarfish stature is combined with frizzly hair such as appears to result from the recent admixtures of the pure or virtually pure Negrito stock of the Andamans with blood from the mainland of India or Burma. Dr. Hutton observes

that it is just possible that the bow is still in his invention, judging from its existence among the Andamanese. In Travancore, the bow is still used by the Ūrālis, the Muthuvans, the Vishavans, and the Kānikkār.

### Proto-Australoid.

The Negritos must have been early displaced or supplanted by the Proto-Australoid. This dolichocephalic type appears to Dr. Hutton to have had its origin in the West. Sewell reverts to the theory of Australian origins, and, in his account of Mohenja Daro skulls, he definitely associates the Proto-Australoid type with the Australian aborigines on the one hand and with the Rhodesian skull in the other. According to Dr. Hutton, the safest hypothesis seems to be that the Proto-Australoid type in India is derived from an early migration from the West, and its special features have been finally determined and permanently characterised in India itself. It is represented in its purest form in the Veddahs, Malavētans, Irulas, Sholagas, and similar tribes in the hunting stage of Ceylon and Southern India, and perhaps in as pure a form as any in the nearly related Paliyans of the Palni Hills, whose sole weapon is the digging spud. It is this type that is primarily responsible for the platyrhine and dark-skinned elements in India. The contribution of the Proto-Australoid to Indian culture may be the introduction of pottery. The presence of the boomerang as well as also of the blow-gun in South India may possibly be credited to them, and in the domain of religion, Totemism."[27] In North Travancore, the blow-gun is found among the Muthuvans and the Vishavans, as large reeds grow in the locality.

### Conclusion.

The existence of a Negrito strain in the aboriginal population of South India has received additional evidence in Travancore. It has been observed by Lapicque and Dr. Guha among the Kadars and the Pulayans of the Cochin State, and by Dr. Hutton and myself among the Ūrālis and the Kānikkār. Spirally curved hair has been observed by me among the Ūrālis, the Kānikkār, the Malavētans, the Malapantārams, and the Vishavans. They were followed by the Proto-Australoid (Pre-Dravidian). This type is found among the aboriginal tribes of Central and Southern India, and is closely allied to the Veddhas of Ceylon, the Toalas of Celebes, and the Sakais of the Malay Peninsula. The Malavētans, the Muthuvans, the Kānikkār, and others may be regarded as representatives of this group.

At present, there are no distinctly Negrito Communities in India nor has any trace of a Negrito language been discovered. But distinctly Negrito features not only crop up continually from the Himalayan slopes to Cape Comorin, but they also abound in great Megalithic monuments which help

us to some extent to unravel the history of their remote past. The observations of Dr. Hutton, Dr. Guha, and myself go to show that Negrito features crop up among the Kadars and the Pulayans of the Cochin State, and the Ūrālis, the Malapantārams, the Kānikkār and the Vishavans of Travancore.

It is interesting to point out that Megalithic monuments are largely found on the High Ranges of Travancore. Dolmens, Menhirs, and alignments are found in the region of the Ūrālis, the Mannāns, the Malayarayans, and other jungle tribes of Travancore. Mr. Perry points out that all the world over Megalithic monuments exhibit such similarities of structure that they must have been the work of a people showing a common culture. It is also worthy of notice that the reality of a stone using people is evidenced by the use of stones for graves by some of the hill-tribes even now. The dead are buried and a stone is planted at the head and the foot of the grave among the Ūrālis, the Muthuvans, the Mannāns, and the Malayarayans.

Systematic excavations still await the spade of the archæologist in Travancore. Ward and Conner did the earliest of excavations in Travancore. According to them, all the tummli appear to be of a period earlier than the Iron Age.[28] Mr. Bourdillon once picked up a bronze lamp from one of the tummli. No skeletal remains have been so far unearthed to bear any direct evidence of the Negrito race in Travancore. Judged by the nature and contents of the objects found, the Megalithic remains of the Deccan and South India are said to reveal a uniform culture, and it is considered that the Megalithic remains of Southern India are post-Vedic and later than any similar remains of the Central Indian Plateau, from where the culture would seem to have spread southwards.[29] The excavations at Mohenja Daro and Harappa reveal that one of the skulls is Proto-Australoid. A correspondence in type is revealed by one of the South Indian skulls Adichanallur which is classed as Proto-Australoid by Elliot Smith. The physical characteristics observed in the skulls are found among the existing South Indian tribes and among the Veddahs of Ceylon. While the Pre-Dravidian is there time-honoured appellation, Dr. Eickstedt would call them "Weddid," and Dr. Guha, Nishadic. Dr. Hutton has labelled them "Proto-Australoid" after Sewell. The Pre-Dravidian has for long stood the test of time, and it is but fitting that it continues.

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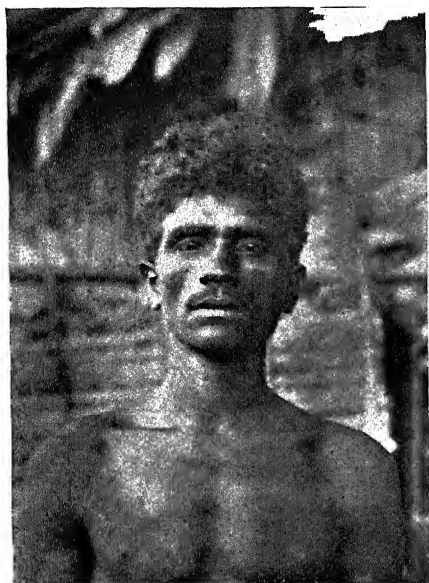
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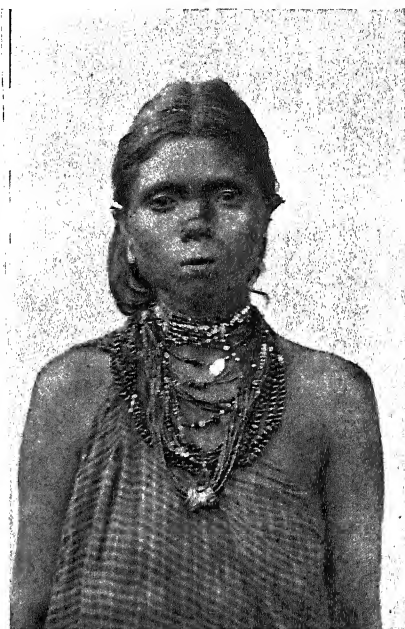


Malapulaye.



Mannān.

| No. of Subjects | Tribes | Language | Locality | |
|---|---|---|---|---|
| 189 | Kânikkâr | Tamil in South | | .. |
| 25 | Do. (Thurston) | Malayalam | South Travancore | .. |
| 83 | Malankuravan | do. | Central Travancore | .. |
| 63 | Malapantâram | Malayalam and Tamil | do. | .. |
| 83 | Malapulayan | Tamil | Anjanad | .. |
| 5 | Do. (Thurston) | .... | .... | . |
| 43 | Mannân | Tamil | High Ranges | . |
| 63 | Malavêtan | Malayalam | South and Central Travancore | . |
| 25 | Do. (Thurston) | do. | .... | . |
| 143 | Malayarayan | do. | Kottayam Division | . |
| 70 | Muthuvan | Tamil on the east Malayalam on the west | High Ranges Thodupuzha | . |
| 21 | Paliyan | Tamil | Vaudamet Periza | . |
| 54 | Pulayan | Malayalam | North of Kuzhithura | . |
| 25 | Do. (Thurston) | .... | Malabar | . |
| 38 | Thantapulayan | Malayalam | Sherthalai | . |
| 83 | Ullâtan | do. | Central Travancore | . |
| 108 | Ûrâli | do. | High Ranges | . |
| 21 | Vishavan | do. | Idyara valley Northern Division | . |

## Summary of Measurements. Pre-Dravidian.

| | Dimensions of Head | | | | | | Proportions of Head | | | Dimensions of Nose | | | | | | Proportions of Nose | | | Stature | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Length | | | Breadth | | | Cephalic Index | | | Height | | | Breadth | | | Nasal Index | | | | | |
| | Average | Maximum | Minimum | Average | Maximum | Minimum | Average | Maximum | Minimum | Average | Maximum | Minimum | Average | Maximum | Minimum | Average | Maximum | Minimum | Average | Maximum | Minimum |
| | 18.1 | 19.3 | 16.9 | 13.5 | 14.5 | 12.6 | 74.2 | 80.7 | 68.2 | 40 | 45 | 35 | 36 | 41 | 31 | 89.6 | 102.2 | 77.0 | 152.9 | 166.2 | .. |
| | 18.5 | 19.4 | 17.8 | 13.6 | 14.2 | .. | 73.4 | 78.9 | 69.1 | 44.0 | 47.0 | 39 | 37 | 43 | 34 | 84.6 | 105.2 | 72.3 | 155.2 | 170.3 | 150.0 |
| | 18.5 | 19.6 | 17.4 | 13.7 | 14.9 | 12.7 | 74.1 | 81.5 | 68.1 | 38 | 45 | 31 | 36.5 | 42 | 31 | 90.6 | 105.9 | 78.7 | 154.2 | 165.2 | 141.3 |
| | 17.7 | 18.7 | 16.8 | 13.6 | 14.3 | 13.0 | 76.0 | 78.8 | 68.0 | 47.5 | 55 | 40 | 33.5 | 36 | 31 | 78.2 | 96.4 | 68.0 | 154.7 | 168.4 | 146.0 |
| | 18.1 | 19.1 | 17.2 | 13.5 | 14.3 | 12.6 | 74.4 | 80.0 | 70.0 | 42 | 47 | 37 | 36 | 40 | 33 | 86.0 | 100.0 | 72.3 | 161.0 | 169.5 | 144.4 |
| | 19.2 | .. | .. | 13.9 | .. | .. | 72.4 | .. | .. | .. | .. | .. | .. | .. | .. | 84.0 | .. | .. | 159.2 | .. | .. |
| | 18.0 | 19.2 | 17.0 | 13.5 | 14.3 | 12.7 | 74.1 | 81.9 | 67.0 | 46 | 51 | 41 | 36.0 | 43 | 31 | 82.7 | 105.7 | 67.4 | 154.5 | 166.5 | 140.0 |
| | 18.1 | 19.1 | 17.1 | 13.6 | 14.4 | 13.0 | 73.5 | 79.4 | 67.3 | 39.5 | 45 | 34 | 34 | 37 | 31 | 92.4 | 104.4 | 73.2 | 153.3 | 162.2 | 146.5 |
| | 18.5 | 19.6 | 17.4 | 13.6 | 14.6 | .. | 73.4 | 78.9 | 69.1 | 44 | 47 | 39 | 37 | 43 | 34 | 84.9 | 102.6 | 71.1 | 154.2 | 163.8 | 140.8 |
| | 18.5 | 19.8 | 17.2 | 13.7 | 14.6 | 12.7 | 73.4 | 81.3 | 66.5 | 39 | 47 | 31 | 37 | 43 | 31 | 84.0 | 100.0 | 62.9 | 157.1 | 172.0 | 147.5 |
| | 18.2 | 19.0 | 17.3 | 13.6 | 14.6 | 12.9 | 73.9 | 78.4 | 69.1 | 45.5 | 53 | 38 | 36.5 | 41 | 32 | 84.6 | 96.6 | 77.9 | 153.9 | 164.2 | 143.9 |
| | 18.3 | 19.3 | 17.8 | 14.4 | 15.6 | .. | 76.3 | 83.0 | 72.3 | 44 | 50 | 40 | 35 | 40 | 30 | 79.3 | 92.7 | 68.0 | 153.0 | 162.6 | 143.4 |
| | 18.3 | 19.1 | 17.4 | 13.1 | 14.7 | 12.1 | 74.4 | 79.0 | 67.2 | 45 | 47 | 33 | 36.5 | 43 | 30 | 84.1 | 94.6 | 75.4 | 159.3 | 168.6 | 144.4 |
| | 18.6 | 19.6 | 17.4 | 14.8 | 17.6 | 12.1 | 74.0 | 98.8 | 66.8 | 40 | 46 | 35 | 33 | 36 | 30 | 78.1 | 95.2 | 67.2 | 152.3 | 159.0 | 147.2 |
| | 18.6 | 19.5 | 17.5 | 13.6 | 14.4 | 13.0 | 73.8 | 78.7 | 69.5 | 41.5 | 46 | 37 | 35 | 37 | 33 | 88.4 | 100.7 | 77.5 | 154.5 | 162.2 | 145.7 |
| | 18.5 | 19.7 | 17.5 | 13.6 | 14.3 | 13.0 | 71.7 | 78.2 | 66.6 | 45 | 50 | 40 | 29 | 36 | 22 | 86.3 | 105.3 | 75.1 | 156.0 | 168.0 | 141.5 |
| | 18.5 | 19.5 | 17.5 | 13.7 | 14.4 | 13.0 | 74.0 | 80.3 | 71.3 | 46 | 55 | 40 | 33 | 37 | 2.8 | 83.8 | 92.3 | 75.0 | 155.6 | 169.0 | 147.0 |

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